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SPECIALISM IN SURGERY

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SPECIALISM is defined as "devotion to a special department of medicine or surgery" (Dorland). A specialist according to Webster is one who devotes himself to a particular branch of a profession. Perhaps the best known description of a specialist is that ascribed to Dr. Nicholas Murray Butler, "One who learns more and more about less and less." Unfortunately the latter description is too often a fitting one.

Specialism in medicine is almost as old as medicine itself, and reached a high degree of development in Egypt, whence it was carried by Egyptian physicians to Persia; according to Herodotus,[1] Darius (King of Persia 521-485 B.C.) had at his court, Egyptian physicians whom he considered the most skilled in the world. Herodotus also stated, "Medicine is practiced among them on a plan of separation: each physician treats a single disorder, and no more; thus, the country swarms with medical practitioners, some undertaking to cure diseases of the eye, others of the head, others again of the teeth, others of the intestines, and some those which are not local."

Medical specialism was also rife in ancient Greece and Rome, but during the Middle Ages it all but disappeared.

Specialism now may be said to be founded upon a somewhat more rational basis than was that which developed in ancient Egypt, Greece, and Rome, in that the various modern specialties have usually been initiated by the invention of special instruments or techniques. Dr. Samuel Harvey[2] states in the introductory paragraph of his excellent small monograph, "The History of Hemostasis," that "the history of surgery is largely written in the record of its technical advances." This is true, perhaps too true. However, certain technical developments, for example, those having to do with the control of hemorrhage, pain, and infection, were, of course, necessary before surgery could progress.

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Ophthalmology was the first well-defined modern specialty. Although a few outstanding physicians such as Sir William Bowman had devoted the greater part of their time and energies to the study and treatment of diseases of the eye, the specialty did not really take hold until the ophthalmoscope was invented by von Helmholtz in 1851.

The development of the cystoscope by Nitze in 1877 played a similar, though somewhat less important role in the development of urology.

The development of thoracic surgery has been influenced by a considerable number of technical discoveries and developments such as the discovery of x-rays by Roentgen in 1895 and their application to thoracic diagnosis, the development of the bronchoscope by Killian in 1897, the development of special techniques for administering anesthesia, such as the Sauerbruch negative pressure chamber, the positive or negative pressure chamber, of Willy Meyer, and, finally, the introduction of intratracheal anesthesia by Meltzer and Auer in 1909.

Although ophthalmology made steady progress in this country after 1851, specialism in general developed slowly in America until the last quarter of the 19th century. In 1876, one of America's most illustrious surgeons, Dr. Samuel D. Gross, stated "it is safe to say that there is not a medical man on this continent who devotes himself exclusively to the practice of surgery, and that American medical men are general practitioners and cover the entire field of medicine, surgery and obstetrics." (Bevan.[3])

However, in that same year, a paper published in the *Virginia Medical Monthly* by Dr. Joseph Sandes[4] of Nashville, Tenn., indicated that some progress in specialism was under way. Dr. Sandes' paper was entitled "The Relative Position Existing between the General Practitioner and the Specialist." He first read two resolutions concerning specialism which had been passed by the American Medical Association in June, 1874: (1) Resolved that this association recognize specialties as proper and legitimate fields of practice; (2) Resolved that specialties shall be governed by the same rules of professional etiquette as have been laid down for the general practitioner. Dr. Sandes discussed the advantages of specialism and warned his audience that the general practitioner must not be arrogant toward or look with disdain on specialists.

Although the American medical profession was slow to adopt specialization, its subsequent development was extremely rapid in this country. Somewhat less than sixty years after the passage by the American Medical Association of the first resolutions concerning specialism, Bevan found that one-third of the physicians in America professed to be specialists. As might have been anticipated, because of the great importance of technical procedures in surgery, the surgical specialties developed more rapidly than did those in medicine. So rapidly has surgery grown and so thoroughly has it been subdivided that Rankin[5] in 1937 made the prophetic statement, "the general surgeon of today lives in the afternoon of his career." It is interesting to contrast this statement with a statement made in 1904 by Professor Halsted[6] that "every important hospital should have on its resident staff of surgeons at least one who is well able to deal not only with any emergency that may arise and to perform any operation known

to surgery, but also to recognize the gross appearances of all the ordinary pathologic tissues and lesions." Few surgeons of today could meet the qualifications described by Professor Halsted.

Barker[7] warned that specialization might pass beyond the limits justified by the stage of development of medical science. The division of surgery has proceeded so rapidly in recent years that one may wonder if it has reached such limits.

The advantages of specialism were well stated by Barker as follows: "The increasing development of specialism in medicine is the logical continuation of the great process of division of labor with concentration upon restricted tasks that has characterized social and economic organizations in general as civilization has advanced. The differentiation of tasks keeps pace with the growing complexity of society to the great advantage both of single workers and of society as a whole. For in the first place, specialization increases productivity. When tasks are subdivided, the division results in operations that are easier of performance than those of undivided work; moreover, work is made easier by frequent repetition. Thus specialization in medicine and surgery as in commerce and industry is a device that has greatly increased the total results of professional labor."

The certain knowledge which comes from intensive study in a limited field and the facility with which one carries out frequently repeated techniques are advantages which may not be overlooked.

Bishop Spalding,[8] in his excellent essay on professional education, made the following terse statement of the dangers of specialism: "Division of labor makes everything cheap—man first of all; and the increasing tendency to specialization may have the effect, not only to lower the standard of professional life, but to interfere with the development in the professions of strong, many-sided personalities, interesting in themselves, and lending dignity to their callings; who, while they are masters in their several departments, are none the less at home in the whole world of human interests and speculations."

Many writers have indicated that specialists are prone to suffer from progressive narrowing of their fields of vision. This is a serious defect in any profession. In medicine it may be fatal. Plato[9] was aware of this danger, for, in "Charmides," he has Socrates relate a conversation which he had had with a physician of the Thracian king, Zamolxis. The physician quoted Zamolxis as saying, "the reason why the cure of many diseases is unknown to the physicians of Hellas is because they are ignorant of the whole, which ought to be studied also; for the part can never be well unless the whole is well."

Osler,[10] in his inimitable way, directed attention to the sclerosing effect of specialization by reciting the story of the old Scotch shoemaker, who, in response to the Dominie's suggestions concerning the weightier matters of life, asked, "D'ye ken leather?"

Gregg,[11] in his "Narrative for a Specialist," has facetiously portrayed the results of this narrowing influence.

Professor Geoffrey Jefferson[12] denies that specialization is necessarily limiting to the mind and general scientific culture of the individual, who, he insists,

is still a physician and must remain one. One will agree that specialization does not necessarily result in a narrow outlook, but one must admit that it often does precisely that. Limitation of vision is an especially serious attribute for a physician to have, for the human body is an extraordinarily complicated mechanism with an amazing interdependence of function between the various parts. It is to be expected, therefore, that derangement of function in one organ or tissue may affect the functions of other organs and tissues, perhaps widely separated anatomically from the original offender.

On first thought one might conclude that even though individual specialists were unable to view the body as a whole, the difficulty could be overcome by consultation between specialists in the various fields, but this will not prove to be a satisfactory solution unless at least one of the consultants is able to comprehend the over-all picture. It appears, therefore, that the only satisfactory solution is to develop specialists, trained in the basic sciences and with a broad view of clinical medicine, yet proficient in the special techniques applicable to their particular field. This is admittedly a large order, but one which is possible of execution, as has been amply demonstrated by many members of this association and by members of other specialty groups. Investigation will show that a large proportion of those specialists who have done outstanding work as investigators, as teachers, and as clinicians, have been well grounded in one or more of the medical sciences or have been broadly trained in clinical medicine or surgery before restricting their work to special fields.

Such eminent clinicians and educators as Bevan,[3] Cheever,[13] and Daniel Fiske Jones[14] have stressed the necessity for broad preliminary training in either general medicine or general surgery preliminary to specialization. That this is desirable may be accepted without question, but it is improbable that this is the only satisfactory road to specialization.

Osler[10] felt that "the most dangerous members of the medical profession were those who were born into it, so to speak, as specialists," and advised preliminary training in one or more of the medical sciences especially in pathology and physiology as the most desirable preparation for entrance either into one of the broad clinical fields or into a clinical specialty. Few would disagree with this point of view, for those so trained develop a broad perspective which they usually retain even though their clinical training may leave something to be desired.

It is possible for hospital services in the specialties to be so conducted that physicians trained on those services will develop and retain a proper perspective toward the broad field of medicine, and will appreciate the fundamental relationship between their specialty and medicine as a whole. In order for a specialty service to so operate, certain requirements must be met: the chief of staff and his associates must be broadly trained in the medical sciences and in clinical medicine; frequent consultations must be had with the other services, especially with the general clinical services, and staff rounds and staff conferences should be held in conjunction with representatives from the medical science departments; patients must be studied from all angles and not viewed as otherwise

empty bodies containing only a heart, a pair of lungs, or a prostate gland; the special techniques applicable to the particular specialty, naturally, must be taught, but not overemphasized; finally, some fundamental research must be carried on, lest the department become sterile.

There are such properly conducted services in operation in this country, which are training, and should continue to train, well qualified specialists. Other good services can be developed, but probably only in limited numbers, because, men of the character, ability, and training, necessary for the proper direction of such services are not to be found in large numbers.

It would seem, therefore, that for the present, properly trained specialists cannot be produced in sufficient numbers by the specialty services alone, but only through cooperation between the specialty services, the general clinical services, and the medical science departments.

One cannot discuss the problems of specialism today without considering the specialty boards. Up to now the specialty boards have unquestionably had a desirable effect on the development of the various specialties. The average period of training of specialists has been increased, and, in the main, the character of training has been improved.

If the various boards continue to move in the right direction, the net result will be of tremendous benefit to the specialties, to medicine as a whole, and to the public.

Unfortunately certain dangerous trends are already becoming apparent. Key[15] and Karsner,[16] in this country, have recently published excellent papers dealing with some of the problems which have already arisen and with other problems which are likely to arise as a result of the influence of the boards. Walshe[17] of England has presented the problems arising in that country as the result of granting special diplomas in the various branches of medicine. These problems are essentially of the same character as those developing in connection with the specialty boards. Too specific requirements as to the exact period of training which candidates for the boards must have in various division of the specialty is undesirable. Failure to give credit for work done in other branches of medicine, even in departments closely allied to the specialty in question, is undesirable and will of necessity lead to a dangerous form of inbreeding. The sclerosing effect of narrow training on the individual is serious but the training of succeeding generations of specialists by those who are constantly becoming more narrow in their outlook will almost inevitably lead to disaster.

Not only is regimentation in training a danger, but a similar danger is evident in relation to practice, in that there is a trend on the part of some of the specialty boards and certain associations of specialists to require absolute limitation of practice to their particular specialty. Unless physicians are allowed, within reasonable limits, to follow the lead of their inclinations and abilities, the field of practice will become less stimulating and they will become less productive. Sigerist[18] has pointed to the results of regimentation in the practice of medicine in Germany. May we take warning and halt this trend toward regimentation in training and in practice. Once regimentation is established by custom, there is the everpresent danger that it may be established by law.

I sincerely hope and believe that the members of this association will take the broad view in regard to the training of thoracic surgeons and may we not be taken in by the overenthusiastic advocates of arbitrary and rigid restrictions on practice.

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LIPOID PNEUMONIA SIMULATING BRONCHOGENIC CARCINOMA

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LAUGHLEN, while working at the Hospital for Sick Children, Toronto, in 1925, observed and reported the first cases of lipoid pneumonia. Three children, all of whom had received instillations of oil into the nose and throat, died of septic pneumonia. One adult with a paralytic dysphagia died of a similar type of pneumonia. It was found later that he had been receiving 1½ oz. of paraffin oil as a laxative three times daily for four and one-half months before death. Histologic preparations showed a peculiar type of endothelial cell reaction and fat stains demonstrated globlets of oil within these phagocytic cells. Laughlen proceeded to show that a similar type of reaction could be produced in the lungs of rabbits by the instillation of albolene into the trachea. Since some of the children had been treated by argyrol instillations also, the effect of these upon rabbits was also tried. This failed to produce the lesions.

Since Laughlen's original publications, many papers on the condition have appeared. In 1937, Ikeda was able to find reports of 106 cases by twenty-four authors in the literature of the ten-year period from July, 1925, to April, 1936. Sixty-eight were in infants and thirty-eight in adults. His reason for writing upon the subject was to call attention to two distinct forms of the disease—the childhood type and the adult type. Lipoid pneumonia of the infantile type, particularly that brought about by liquid petrolatum and its allied preparations, was regarded as representing the initial stage of the adult type. It terminated, as a rule, either in resolution on withdrawal of the offending agent or death due to complicating secondary pneumonia. The pathologic nature of the adult type was regarded as essentially that of a paraffinoma of the lung. It extended in its various stages of development from an early, nonsuppurative, proliferative, interstitial pneumonitis to a chronic, granulomatous, foreign-body reaction terminating in the final stage with widespread fibrosis and tumefaction of the area. He called attention to the necessity of differentiating the lesions from primary and secondary tumors and stated that confusion had arisen not only in the x-ray pictures but at autopsy.

Moel and Taylor, writing upon the subject under the title "Oil Aspiration Pneumonia," stated that oil entered the lung in three ways, through the mouth, by being instilled into the nose as drops, and through tracheotomy openings. The responsible lipoids were divided into three groups: (1) animal oils—halibut liver, cod liver oil, milk and egg-yolk; (2) vegetable oils—castor oil, olive oil, wheat germ oil; (3) mineral oil—liquid paraffin. The predisposing conditions were listed as (1) perforated palate; (2) forceful feeding of crying and debilitated infants; (3) neurologic conditions causing dysphagia; (4) debilitating conditions (bedridden patients to whom paraffin oil was given to relieve constipation); (5) upper respiratory infections treated by nasal instillations.

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The pathological findings were divided into three groups, (1) diffuse acute, (2) an intermediate diffuse chronic associated with a diffuse fibrosis (in this stage acute pneumonia might supervene) and (3) chronic localized (tumor-like paraffinomas).

Pinkerton reported a case in a man 61 years of age with paralysis agitans who took paraffin oil by mouth for constipation. At autopsy a paraffinoma was found with apparently secondary adjacent abscesses. The pulmonary vessels showed paraffin emboli and the spleen contained numerous tuberclelike nodules, which, on staining, proved to be secondary paraffinomas.

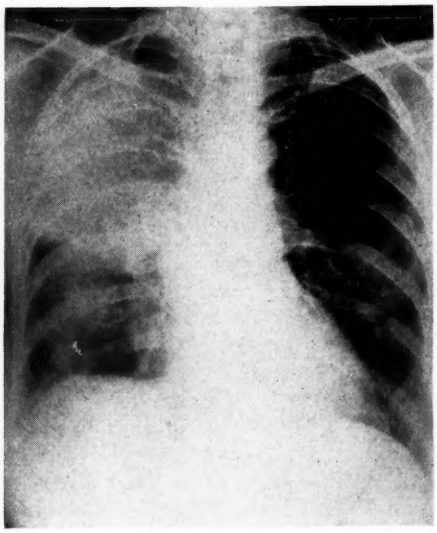

Fig. 1.—Case 1. Posteroanterior film. Infiltrative lesion involving chiefly upper half of right lung and associated with a little evidence of retraction. Some shadow in lower left lung field.

Stokes reported the case of a man 62 years of age who had an x-ray of the chest in 1939 which showed no intrapulmonary lesion. In November, 1940, he noted undue fatigue, loss of 6 lb. in weight, 1 ounce of thin, watery sputum and a fever of 99 to 100° F. By December the cough had increased in severity, the sputum was blood-streaked, he had night sweats and was unable to work. In January, 1941, an x-ray showed a density in the apex of the right lower lobe with a cavity. Bronchoscopy did not demonstrate a tumor. The cough and fever continued and the sputum increased to 4 to 6 oz. daily. A further x-ray still showed a density with a cavity. A second bronchoscopy did not reveal a tumor. In February, 1941, the right lower and middle lobes of the lung were removed. The patient recovered. The pathologic diagnosis was lipoid pneumonia. A history of the nightly use of petroleum jelly in the nose for several years and of the use of Va-tra-nol in the nose for more than a year was then obtained.

CASE 1.—Miss G. A., aged 65, a retired schoolteacher, had always enjoyed good health. In the latter part of April, 1946, she felt ill and "achey" all over. She did not get well and three to four weeks later saw a physician for the first time. He diagnosed pneumonia. A dry cough with a little phlegm in the morning had been present from the beginning. X-rays made on May 16, 1946, showed a diffuse infiltration of the whole right lung with an area of atelectasis in the region of the middle lobe and a slight shift of the mediastinum to the affected side. There was also a mild infiltration in the lower left lung field. She improved a little on penicillin. X-ray on June 6, 1946, showed a lessening of the shadows in the lower portion of the lungs but if anything an increased density of shadow in the right upper and middle lobes. Bronchoscopy June 26, 1946, revealed some reddening of the bronchial mucous membrane and a small amount of mucopurulent sputum on the right side. A further x-ray on July 10, 1946, showed continued improvement on the left side but the right was much the same.

Fig. 2.—Case 1. Lateral film. Major disease in upper lobe but some involvement of upper part of lower lobe.

When first seen by me on July 18 the patient had lost 35 pounds and looked thin and ill. She was quite short of breath on any mild exertion. There was no clubbing of the fingers. There was decreased movement of the right side of the chest and a little mediastinal shift to the right. There was decreased resonance over the right chest especially anteriorly where the breath sounds were harsh and blowing in character. There were no râles. It was thought that the most likely diagnosis was carcinoma of the bronchus and that a thoracotomy, although not hopeful, was justifiable.

Operation.—July 31, 1946. Intratracheal cyclopropane anesthesia. The right chest was opened through the sixth interspace. The upper lobe was broadly adherent to the chest wall and contained a very hard mass the size of an orange. There was also a nodular infiltration of a considerable part of the lower lobe and nodules several millimeters in diameter could be seen and felt beneath the pleura. The whole of the lung surface looked edematous. One of these nodules was removed and a quick section done. The lesion was reported as inflammatory. There was no enlargement of the hilar lymph nodes and no mass could be felt in the larger bronchi. It was thought to be some sort of inflammatory condition that had not been encountered before and that removal of the lung was neither feasible nor justifiable. Further material was obtained for examination, 100,000 units of penicillin placed in the pleural cavity and the chest closed.

Pathology.—The specimen consisted of two small pieces of tissue each about 2.5 cm. in length, of a grayish color. Microscopically the appearance was typical of lipoid pneumonia. A great majority of the alveoli were distended by collections of vacuolated lipoid containing macrophages. There was a variable amount of edema fluid in some of the air sacs. In some places the alveolar walls were thickened by an increase in fibrous tissue. Here and there where the fibrous tissue reaction was more extensive the alveoli had been replaced by a loose-textured collagenic material studded with a few variable-sized fat vacuoles. These areas were frequently associated with focal collections of inflammatory cells, chiefly of the lymphocytic type.

Recovery from operation was slow but uneventful. An x-ray made November 12, 1946, showed some clearing of the lung and there has been improvement in the general health although she still remains an invalid.

A review of this patient's past history in the light of the proved diagnosis disclosed the fact that some twelve years previously she had used oil drops in her nose over a period of about one month. At no time was an excessive amount used and this was the only time in her life that oil therapy had been employed in any form.

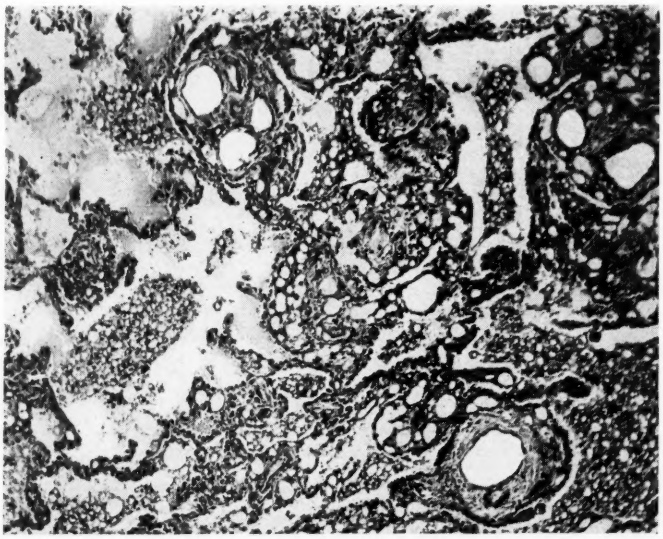

Fig. 3.—Photomicrograph, Case 1.

CASE 2.—Mrs. M. S., aged 59, housewife. Patient had an x-ray of her chest made in December, 1945, as part of a routine survey and not because she thought there was anything the matter. This film showed a shadow in the right upper lung field. A repeat x-ray in April, 1946, showed no change in the condition. She was seen then by a chest physician who obtained a history of slight fatigue and slight dyspnea on exertion. There was a past history of severe chest colds with cough and high fever 9 and 12 years previously. There were no abnormal findings on chest examination. When first seen by me on June 4, 1946, she complained of some discomfort in the upper right chest and had lost 5 lbs. It was thought that this was probably attributable to worry over the knowledge that she had something wrong in her chest, since she was an introspective type. Further x-rays of the chest including laminographs were obtained. These showed a dense shadow in the upper right chest close to the mediastinum, which was interpreted as a completely atelectatic upper lobe. There was no recognizable shift of the mediastinum. Bronchoscopy revealed no tumor but a change in the

direction of the right bronchial tree consistent with atelectasis of the upper lobe. It was thought that the probable diagnosis was carcinoma of the upper lobe bronchus, and thoracotomy was advised.

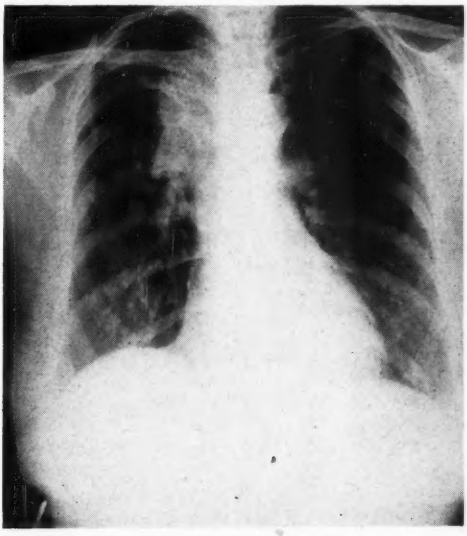

Fig. 4.—Case 2. Posteroanterior film showing shadow, which proved to be completely atelectatic upper lobe.

Fig. 5.—Case 2. Planograph.

Operation.—July 26, 1946. Intratracheal ether anesthesia. The right chest was opened through a posterolateral incision with resection of the sixth rib. There were very few adhesions to the chest wall. The upper lobe was reduced to perhaps one-fifth of its normal size, its bulk being made up of a very hard mass 6 cm. in diameter about which was a relatively small amount of completely atelectatic lung. There was a puckering of the surface of the

mass. Although it presented an unusual appearance it was felt that it was probably an epidermoid carcinoma. There was one nodule on the mediastinal pleura just in front of the anterior vein which looked like an implant. There was no enlargement of the hilar lymph nodes. A pneumonectomy was carried out, the nodule coming away readily with a bit of pericardium. The chest was closed with 200,000 units of penicillin in the pleural space. The postoperative recovery was uneventful.

Pathology.—Throughout this consolidated portion of lung the alveoli were more or less filled with large vacuolated cells, the nuclei of which were pushed to one side. These had the typical appearance of histiocytes filled with fat. The alveolar walls throughout were thickened and, in some areas, the fibrosis had become sufficiently marked to obliterate large numbers of alveoli. In these fibrotic areas, numerous foreign-body giant cells could be seen surrounding clear, vacuolated spaces.

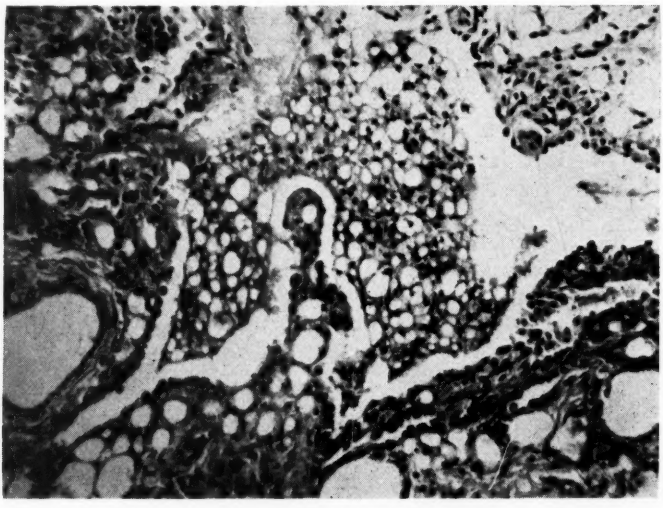

Fig. 6.—Photomicrograph, Case 2.

The general picture was typical of a long-standing lipoid pneumonia, with areas of fibrosis and obliteration of lung parenchyma. Scattered throughout the lung tissue numerous lymphoid follicles could be seen which were not sharply defined and, here and there, showed definite germinal centers.

The patient has made a satisfactory recovery from the pneumonectomy. A review of the past history in the light of the pathologic findings disclosed the information that for a short time, a month or so, while she had a cold twelve years before, she had used intranasal oil drops. At no time, she felt, had the amount been excessive.

DISCUSSION

It would appear that this is a condition which must be considered in the differential diagnosis of carcinoma of the bronchus. The disturbing feature is that a history of the use of oil drops would almost certainly not have been considered of importance, since in neither case was the amount excessive either from the point of view of individual instillation or the length of time over which the treatment extended. The suggestion would seem to be that there must be an

individual susceptibility to the development of lipoid pneumonia, since so many persons use larger amounts of oil than either of these patients did without apparent ill effects. The roentgenograms of both patients were reviewed by several competent radiologists and while they could not be considered perhaps as typical of bronchogenetic carcinoma, that was considered as the most probable diagnosis in each case. In retrospect, a biopsy and quick section in Case 2 would probably have disclosed the true nature of the lesion and saved the patient from an unnecessary pneumonectomy. The lesion was in the healed stage and would almost certainly have remained in its then quiescent state.

I am indebted to the x-ray department of the Toronto General Hospital for the roentgenologic studies and to the Department of Pathology of the University of Toronto for the pathologic descriptions.

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GASTROGENOUS MEDIASTINAL CYST

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GASTROGENOUS mediastinal cysts are a rarity, only twenty-one having been previously recorded in the literature. The following case is reported because it is only by the accumulation of such records that one can arrive at knowledge of the diagnosis and correct treatment in these cases.

CASE REPORT

The patient, a 5½-year-old girl, was first seen in October, 1944. A routine physical examination with suspicious chest findings, followed by a chest x-ray, had led to her admission. Outside of some difficulty in gaining weight, there had been no definite symptoms. Specifically, there had been no cough, dyspnea, or other complaint referrable to the chest.

Physical examination at this time showed a well-developed girl who was somewhat underweight. The only abnormal findings were dullness and diminished breath and voice sounds over the right lower lobe posteriorly.

Laboratory work-up revealed the red blood count to be 4.4 million with 13.3 Gm. of hemoglobin. The white blood count was 8,200 with 64 per cent polymorphonuclears, 26 per cent lymphocytes, and 5 per cent monocytes. Urinalysis was normal. The blood Wassermann and Kahn tests were negative. Agglutination tests for typhoid, paratyphoid, brucellosis, and dysentery were negative. Examination of the stools was negative for ova and parasites. The complement fixation test for echinococcus disease was negative. Skin tests for tuberculosis and echinococcus disease were negative. The chest x-ray taken before admission (Figs. 1 and 2) revealed a large circumscribed mass involving the greater portion of the right lower chest, especially posteriorly.

The patient was entirely asymptomatic during her whole hospital stay, her temperature never exceeding 100° F. She was discharged on the tenth hospital day with a diagnosis of unclassified tumor of the right lung.

In May, 1945, seven months later, the patient was readmitted. She had been entirely well during the interim. Physical examination revealed no change in the findings previously noted.

The red blood count was now 4.51 million with 12.3 Gm. of hemoglobin. The white blood count was 10,700 with 65 per cent polymorphonuclears, 1 per cent eosinophiles, 1 per cent basophiles, 31 per cent lymphocytes, and 2 per cent monocytes. Urinalysis was normal. X-rays of the chest showed the lesion to be entirely unchanged.

On May 12, 1945, operation was performed, the preoperative diagnosis being a cystic tumor of the posterior mediastinum. With the patient in the left lateral position, removal of the eighth rib with section of the vertebral ends of the sixth and seventh ribs was carried out. The pleural space was then opened, disclosing a large cyst of the posterior mediastinum measuring approximately 9 cm. in diameter. It extended from the third rib superiorly to about an inch above the diaphragm inferiorly, and was closely adherent to the posterior aspect of the upper half of the lower lobe posteriorly. The cyst was purposely tapped and its thin opalescent, light, coral-colored fluid aspirated. It was then excised by blunt and sharp dissection. Inferiorly, it appeared to be attached to the right side of the esophagus in close proximity to the diaphragm. Closure was carried out in the usual fashion, a rubber tube drain being brought out the anterior extremity of the wound.

The postoperative course was entirely uneventful and the patient was discharged on the twenty-first postoperative day. Her final checkup x-ray showed the lung completely re-expanded (Figs. 5 and 6).

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PATHOLOGY

The cyst wall (Figs. 3 and 4) was found to be composed, for the most part, of a fibrous membrane which ranged from 2 to 5 mm. in thickness. One area about 3 cm. in diameter and 5 mm. in thickness, grossly resembled gastrointestinal mucosa, its lining surface being granular, soft, and pink.

Microscopic examination of sections revealed an almost perfect reproduction of the structure of the wall of the stomach. The mucosa was moderately thick and composed of characteristic tubular glands with mucous neck glands, chief cells, and parietal cells in the usual distribution. The only variation was an uneven mucosal surface with festooning not ordinarily present in the stomach. The muscularis mucosa and submucosa showed the usual structure. The muscularis was well developed with three distinct layers identifiable. Myenteric neural plexuses with ganglionic components were present.

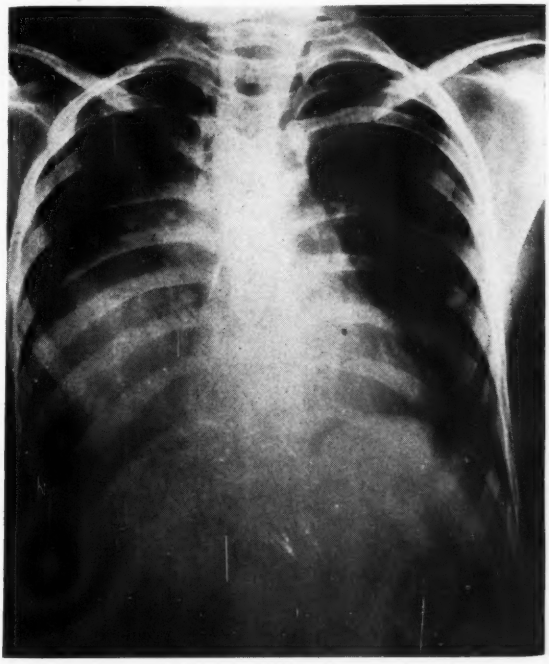

Fig. 1.

Examination of the fluid content of the cyst revealed, on centrifuging, crystalline material which was doubly refractile and was felt to represent lipoid, including cholesterol. Analysis revealed a cholesterol content of 10 mg. per cent and total proteins of 1.6 grams per 100 c.c. The pH was 7.8. There was no free hydrochloric acid and no pepsin. Cultures taken from the cyst fluid were negative.

The pathological diagnosis was gastrogenous cyst.

DISCUSSION

In a comprehensive review of the literature, Olken[13] found ten reported cases of mediastinal cysts partially or completely lined by mucous membrane

resembling gastric mucosa. To these, he added an eleventh case. Two other cases reported by Olken as gastrogenous cysts are not included here because there seems to be some question as to whether they were truly gastrogenous.

In addition to the ten gastrogenous cysts, he reports eight instances of mediastinal cysts lined by mucosa of small bowel and mucosa resembling that of the esophagus (sometimes ciliated as in its embryonic state). The present report is, however, confined to a discussion of cysts duplicating the structure of the stomach.

Fig. 2.

The age and sex incidence of these patients are tabulated, as well as the location of the tumor and the pathological findings. Finally, the prevailing theories as to origin of these cysts are adequately discussed, and are summarized as follows: "They (gastric and enteric cysts of the mediastinum) have been ascribed to the pinching off of a bud or diverticulum of the embryonic foregut; to an intrathoracic remnant of the omphalomesenteric duct; and to an embryonic diverticulum or epithelial remnant capable of producing intestinal or gastric mucosa."

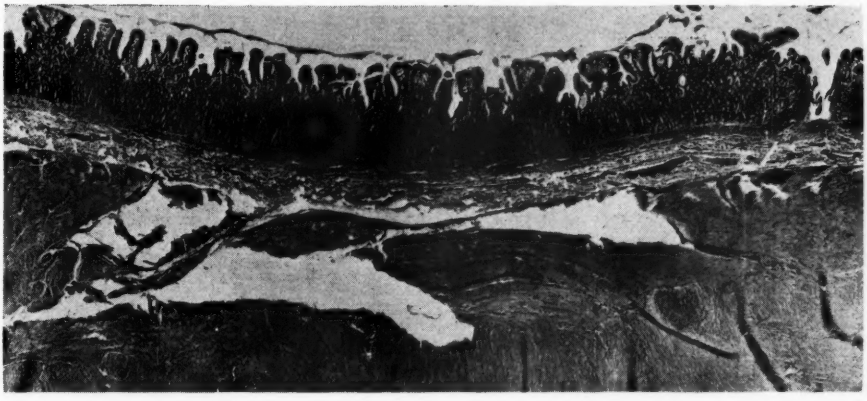

Fig. 3.

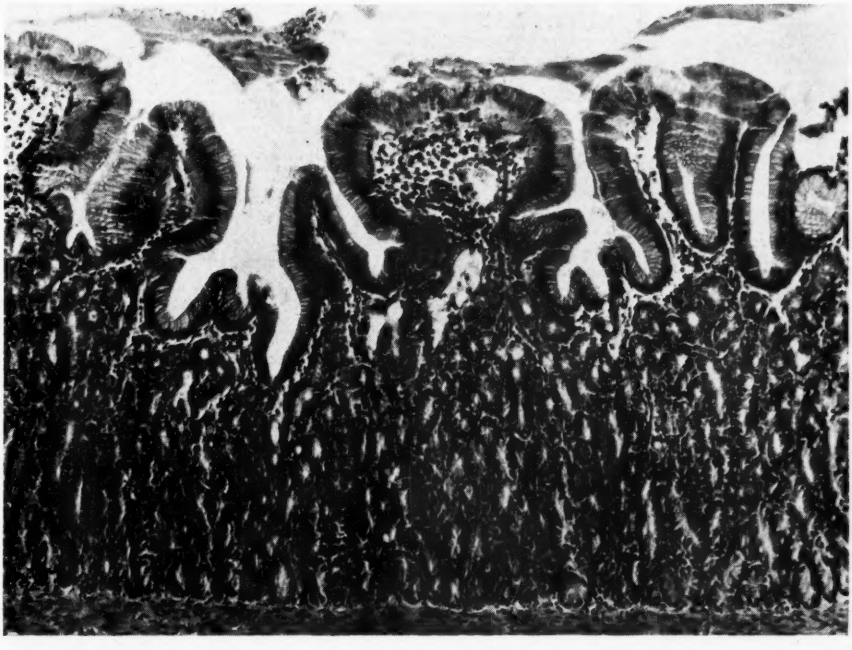

Fig. 4.

We have found nine additional cases of gastrogenous mediastinal cyst in the literature in addition to the twenty-first case herein presented. Two of these were reported by Ward and Krahl,[9] two by Schwarz and Williams,[10] one by Wyllie and Pilcher,[12] three by Ladd and Scott,[14] and one by Steele and Schmitz.[15]

TABLE

CASE	AUTHOR	AGE	SEX	HISTORY	OPERATION	RESULT	TUMOR SITE
1	Staehelin-Burckhardt (1909)	9 mo.	F	Death from meningitis following operation for spina bifida; cyst an incidental post-mortem finding.			Right side esophagus; attached to esophagus but not communicating
2	Mixter and Clifford (1929)	22 mo.	M	Fever, dyspnea, vomiting, brassy cough, weight loss.	Two-stage operation, marsupialization followed by excision.	Recovered	Right posterior thorax from apex to diaphragm and attached to diaphragm
3	Mixter and Clifford (1929)	7 wk.	M	Acute distress on nursing; brassy cough.	Two operations failed to find cyst.	Died	Right paravertebral gutter; no attachments
4	Entz and Orosz (1930)	11 mo.	M	Malnutrition	Marsupialization.	Died	Right posterior mediastinum
5	Smith (1930)	13 mo.	M	Pneumonia (?)		Died	Right mediastinum
6	Poncher and Milles (1933)	29 mo.	M	Attacks of abdominal pain and melena.	Exploratory thoracotomy.	Died	Right posterior mediastinum
7	Boss (1937)	3 yr.	M	Hemoptysis	Two operations	Died	Right mediastinum
8	Seydl (1938)	3½ mo.	F	Cough and hemoptysis		Died	Right posterior pleural space
9	Nicholls (1940)	8 yr.	F	Chronic empyema with draining sinus 4 yr.; attempted thoracoplasty on several occasions prior to correct diagnosis.	Excision	Recovered	Right posterior pleural space
10	Ward and Krahl (1942)	9 wk.	M	Tarry stools with hemoptysis or hematemesis; cough and dyspnea; bulging of right thorax.		Died	Right anterolateral thorax
11	Ward and Krahl (1942)	8 wk.	M	Attacks of dyspnea and cyanosis; (spontaneous pneumothorax.)	Aspiration of air	Died	Right posterior thorax
12	Schwarz and Williams	4 mo.	M	Dyspnea, apnea, and cyanosis; excoriation of skin about drainage tube; preoperative diagnosis aberrant stomach.	One-stage excision	Died	Right posterior thorax
13	Schwarz and Williams	23 yr.	M	Cough and chest pains; attacks of unconsciousness preceded by dyspnea.	One-stage excision	Recovered	Right posterior thorax; attached to esophagus
14	Carlson (1943)	4 mo.	M	Dyspnea, dysphagia, and bulging of right chest.	Three-stage operation; marsupialization and excision	Recovered	Left posterior
15	Wyllie and Pilcher (1943)	12 mo.	F	Poor feeding and enlargement of abdomen.	One-stage excision.	Recovered	Right posterior chest, retropleural

I

DIAMETER GREATEST	PATHOLOGY	FLUID ANALYSIS	X-RAY REPORT
1 cm.	Cyst lining containing gastric and esophageal mucosa		
6.5 cm.	Wall of cyst showing typical gastric mucosa, submucosa, and muscularis; Paneth's cells numerous; nerve trunks and ganglia	Acid; sp. gr. 1,010	Chest fluid
5 cm.	Cyst lined by gastric mucosa with parietal and chief cells; smooth muscle and serosa		Admission x-ray showed "pneumonia"; lipiodal injected into cyst
	Cyst lining showing typical gastric structure		
12 cm.	Cyst lined partially by gastric and partially by ciliated stratified epithelium		
12 cm. and 6 cm.	Two cysts lined by gastric mucosa; three muscle layers in wall		Increased density right posterior chest
6 cm.	Cyst lined with mucosa resembling stomach; peptic ulcer penetrating right lung		Cyst of lung (?)
	Cyst lined with mucosa typical of stomach; peptic ulcer perforating into right lung		Right-sided pulmonary lesion
	Cyst lined by gastric mucosa		Lipiodol showed cavity
5 cm. and 7 cm.	Two cysts lined by gastric mucosa with acid cells, three muscular layers, and serosa; right upper lobe bronchus communicated with smaller cyst		Multilocular cyst of right lung increasing in size
3 cm.	Cyst lined with typical gastric mucosa and wall in one area; other portions showed duodenum with pancreatic tissue in its muscle wall		Large right-sided pneumothorax and pulmonary cyst
10 cm. (?)	Gross appearance of normal stomach, microscopically typical gastric mucosa with chronic ulcers; two muscle layers	pH=1.84–2.44. Trace free HCl. Chlorides 143 millimols per liter. 6.2 c.c. of N/10 NaOH neutralized 10 c.c. peptic acid, rennin activity present	Cystic disease of lung; lipiodol bronchograms neg.; barium by mouth neg.
8 cm.	Incomplete mucosal lining; mucous membrane resembling stomach and small intestine; parietal and Paneth's cells present; three muscle layers		Rounded, partly calcified mass 8 cm. diam. right posterior mediastinum
8 cm.	Cyst lined by mucosa varying from gastric structure to that of small bowel; parietal cells are present; two layers smooth muscle		Large cyst of left chest with some pneumothorax
Contained 8 oz.	Cyst attached to paravertebral gutter filling almost whole right chest; sections of wall showed gastric mucosa and three muscle layers		Opacity right lung field with rounded shadow

TABLE I.

CASE	AUTHOR	AGE	SEX	HISTORY	OPERATION	RESULT	TUMOR SITE
16	Olken (1944)	Still-born	M				Right posterior chest, retropleural
17	Ladd and Scott (1944)	7 mo.	F	Cough, fever, cyanosis, and abdominal cramps; bulging of right chest posteriorly.	Two-stage operation; marsupialization followed by attempted excision; esophageal fistula resulted.	Died	Right posterior chest, retropleural
18	Ladd and Scott (1944)	3 wk.	M	Routine x-ray of chest because of club feet.	Marsupialization followed by several curettings	Recovered	Left posterior chest, retropleural
19	Ladd and Scott (1944)	2 yr.	M	Hemoptysis (or hematemesis), cough and fever	Several operations; finally cyst curetted and treated with iodine packing	Recovered	Right paravertebral gutter
20	Steele and Schmitz (1945)	15 yr.	F	Routine fluoroscopy, asymptomatic; cardiac murmur disappeared after removal of cyst.	One-stage excision	Recovered	Left posterior chest, retropleural
21	Valle and White (1946)	22 mo.	F	Pulmonary symptoms shortly after birth: cold, cough, cyanosis, hoarseness, purulent expectoration, hemoptysis.	One-stage excision of cyst and pneumonectomy	Died	Paravertebral region above diaphragm
22	Author's case	5½ yr.	F	Routine physical examination; asymptomatic	One-stage excision	Recovered	Right posterior mediastinum

Schwarz and Williams, in reviewing the literature, have attempted to correlate the physical and pathological findings with the physiologic activity shown by the tumor epithelia. These authors also present an interesting discussion of the possible part played by so-called "organizer substances" in the formation of these tumors. They point out that the frequency with which gastrogenous cysts occur in the right hemithorax may be merely another instance of "organizer" influence. Ladd and Scott, in a beautifully illustrated paper suggested the possible relation of gastrogenous cysts to reduplications of other portions of the gastrointestinal tract.

Reference to the accompanying table brings out several points of interest, even though the number of cases being considered is small (Table I).

It is seen that these cysts have occurred primarily in infants and young children. One patient was 23 years of age, and another 15. The rest of those reported have been under 5½ years of age at the onset of their symptoms or at the time of operation. Fourteen cases have occurred in males as against seven in females.

The location of the cysts have been remarkably constant. In eighteen of the twenty-one cases, it has been in the right hemithorax; and in seventeen, it has been definitely located posteriorly.

(CONT'D)

GREATEST DIAMETER	PATHOLOGY	FLUID ANALYSIS	X-RAY REPORT
8 cm.	Cyst showed no communication with any other structure; its wall lined by gastric mucosa with acid cells; three muscle layers present		
6 cm.	Cyst has common muscular wall with esophagus; excision resulted in esophageal fistula; wall of cyst lined by gastric mucosa with parietal and chief cells; two muscle layers	Acid reaction	8 cm. spherical mass filling most of right thorax
5 cm.	Cyst attached by pedicle 1.5 cm. wide to left wall of esophagus	Acid reaction	5 cm. rounded mass in left posterior chest
5 cm. (?)	Cyst wall and curettings showed mucous membrane identical with gastric mucosa	pH=4; peptic and rennin activity	Orange-sized rounded mass; right posterior mediastinum
12 cm.	Cyst closely attached to aorta and vertebral bodies; portion of wall of cyst lined by gastric mucosa with chief and parietal cells; smooth muscle and nerve elements in cyst wall		Spherical shadow 8 cm. diameter posteromesial left hemithorax; erosion pedicles fourth and fifth vertebrae
5 cm. (?)	Cyst communicated with right lower lobe; microscopic analysis showed elements of normal stomach		Infiltration of right lower lobe; cyst formation in right hilar region; bronchiectasis as revealed by bronchogram
9 cm.	Portions of cyst wall almost perfect reproduction of wall of stomach; chief and parietal cells present; three layered muscularis with neural plexuses	pH=7.8. No free HCL. No pepsin	Large circumscribed mass involving most of right lower chest especially posteriorly

Diagnosis remains an extremely difficult task. There is no symptom or symptom complex which is pathognomonic, several cases (including that under discussion) having been practically asymptomatic. The diagnosis may be suspected when a cystic tumor is demonstrated in the posterior mediastinum in an infant or young child, especially when it is located on the right side of the thorax. The x-ray examination is usually the most helpful of all diagnostic procedures, frequently, though by no means always, demonstrating the tumor, its location, and sometimes the fact that it is cystic.

Aspiration has been used as a diagnostic as well as a therapeutic procedure. Unfortunately, in most of the reported cases, there has been either no analysis or an incomplete analysis of the cyst fluid. The reaction of the fluid has been recorded as acid in five cases, in one of which the pH was found to be four; and in another, it varied from 1.84 to 2.44. Two other cases presumably fall in this group, since active peptic ulcers were found in the cysts. In our own case, the pH was 7.8 and no free hydrochloric acid was present. There are no data on the remaining thirteen cases. Aspiration of cyst fluid with chemical analysis is undoubtedly a worth-while diagnostic procedure.

Fifteen of the twenty-one patients were submitted to operation. Nine of these recovered. Four of those recovering were treated by a stage operation with

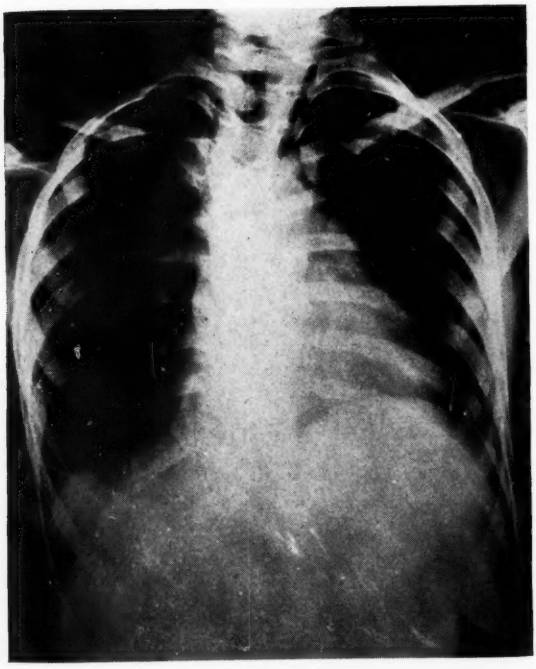

Fig. 5.

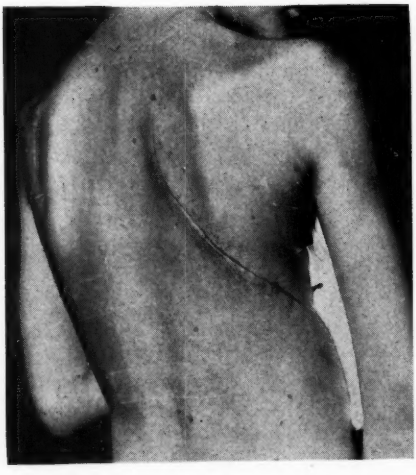

Fig. 6.

marsupialization and four by primary excision. There seems to be no question but that operation is advisable in all cases, both because the exact type of tumor to be dealt with is usually not definitely known preoperatively, and because these tumors almost always cause symptoms quite early in life. The high mortality is not surprising. Many of the patients are infants in extremely poor shape, and in these cases a stage operation with marsupialization of the cyst has in the past sometimes seemed most wise. With modern advances in the preparation of patients for operation and with improved techniques for the administration of anesthesia, we feel that a one-stage removal of the tumor will almost always be the procedure of choice.

The experience of Ladd should be kept in mind when attempting excision of these cysts. In one of his cases, a gastrogenous cyst shared a common muscular wall with the esophagus. Complete excision of the cyst resulted in an esophagopleural fistula with subsequent fatality.

SUMMARY

A case of gastrogenous cyst of the mediastinum is reported. Diagnosis and treatment are discussed in the light of a complete review of the literature.

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MEDIASTINAL ENTEROCYSTOMA

Report of a Case in a Seven-Month-Old Child With Impending Suffocation, Operation, and Recovery

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CONGENITAL deformities both in the lungs and mediastinum and its organs have long been well known and have been thoroughly analyzed from the standpoint of pathologic anatomy. Clinical experience during recent years has taught us that many of these malformations sooner or later give rise to life-endangering complications. Not until the great advance in thoracic surgery during the last decade (due largely to the work of such surgeons as F. Sauerbruch, Evarts A. Graham, Edward D. Churchill, John Alexander, R. Gross, C. Crafoord, A. Blalock, and Richard Sweet), however, have these deformities been given much attention in clinical work. Thus, not until recent years have they been subjected to clinical analysis and the patient given appropriate surgical treatment and a good chance for complete recovery.

Mediastinal cysts of the enterocystoma type with mature gastric mucosa belong to the rarities. This, together with the facts that the cyst in question caused acute and life-endangering tracheal compressoin and that its radical removal in a 7-month-old child led to complete recovery, prompted us to report the following case.

REPORT OF A CASE

History.—The female baby was treated at the Banck's Children's Hospital, Hälsingborg, from May 31 to June 17, 1946, where she was given the diagnosis of bronchopneumonia, intrathoracic tumor (dermoid cyst?), and secondary anemia. She was transferred to the Surgical Hospital in Lund because of an intrathoracic tumor compressing the trachea and right bronchus.

Family History.—The patient had three elder brothers and sisters, all well. The parents were in good health.

Previous History.—Spontaneous delivery followed a full-term pregnancy. The birth weight was 3,250 Gm. The condition seemed normal at birth and remained so during the first two or three months. The child failed to gain weight normally, however, and after three months, citric acid milk was given in addition to breast milk. At the age of 4 months she began to be troubled by chest râles, at first mild and then more and more severe. The mother noted that the child occasionally had difficulty in breathing, lasting up to two or three minutes, during which she became cold and pale. Between these attacks the child seemed to be completely healthy.

At the end of May, 1946, the child fell ill with a severe cough and a fever between 38.7 and 39.2° C. The last four days before her admission to the Hälsingborg Children's Hospital, stridor and hoarseness were observed. The last two nights before admission the child had great difficulty in breathing and could not sleep. She was admitted on May 31 in poor general condition, with a severe cough and marked dyspnea. Bronchopneumonia was observed basally in the right lung field with atelectasis of the right lower lobe. Roentgenographic and fluoroscopic examination revealed a rounded, circumscribed tumor superiorly in the right lung field, apparently situated in the posterior mediastinum and compressing the trachea (Fig. 1).

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After intensive treatment with sulfonamide drugs, penicillin, oxygen, and blood transfusions, the child grew better and the temperature returned to normal. A certain degree of stridor persisted, however. The patient was transferred on June 24 to the Surgical Hospital in Lund.

Physical Examination and Clinical Course.—The child was fairly well developed for her age, 7½ months, but thin. She weighed 5,810 Gm. The tonus and turgor were diminished. Severe stridor was heard, both on inspiration and expiration. Numerous râles and rhonchi were heard over the right lung field. No other signs were seen on physical examination. The blood count showed a hemoglobin content of 81 per cent, 4,000,000 erythrocytes, and 17,100 leucocytes. The pulse, temperature, and sedimentation rate were normal.

Oxygen was administered immediately upon admission. Stimulants were given and the diet regulated by the addition of citric acid milk. The condition remained satisfactory the first two days, though the stridor persisted. On the night of June 25, the child had two bad attacks of cyanosis and dyspnea and another seizure the next morning. On the morning of June 26 reliable roentgenograms were obtained after several unsuccessful attempts.

The roentgenograms showed on the right side, a circumscribed, rounded lesion 4 to 5 cm. in diameter originating in the superoposterior part of the mediastinum. The trachea was squeezed to the right by the formation and the bronchus arched forward and compressed so that its lumen was only 1 or 2 mm. wide at one site (Fig. 2). The medial pulmonary field below the growth was hazy and showed linear markings. These observations were considered to point to an expanding process emanating from the superoposterior part of the mediastinum, a dermoid cyst, for example, and to atelectasis in the right lower lobe.

The films revealed severe compression of the trachea and right bronchus by a tumor in the right posterior mediastinum, and it was decided to operate immediately in view of the threatening condition and the undoubtedly poor prognosis otherwise.

Operation (H. B. W.), consisting of *right thoracotomy* and *removing of a mediastinal enterocystoma* was performed under cyclopropane and oxygen anesthesia. Intubation with a fine rubber catheter and a tightly fitting mask was used. The child was placed in the lateral recumbent position with the right side up. Subperiosteal resection of the fifth rib on the right side was done with a modified Crafoord incision. The pleura was opened. The entire upper part of the right pleural cavity, apically and mediastinally, was filled by a round, orange-sized tumor. The growth was not connected to the lung, but appeared to arise apically and medially in the posterior mediastinum. Over the tumor, which was very firm, stretched a number of veins, wider than goose quills. After a couple of the large venous trunks were ligated and a number of others were relaxed with silver clips, the pleura over the tumor was split. The tumor was then detached laterally, anteriorly, posteriorly, and medially, mainly with blunt dissection but in some places with a scissors as well. It was firmly anchored superoposteriorly, however, where it proceeded in toward the vertebral column. When it was loosened at this site, a difficult process, for large distended venous trunks got in the way, the tumor capsule burst, and a large amount of fluid ran out. The fluid was greenish yellow, slightly turbid, and odorless. It did not contain hair or any other products typical of dermoid cysts. When this part of the tumor was loosened, the esophagus and trachea were bared medially. After the tumor had collapsed, it was fairly easy to detach the remainder of its stalk and the growth was then removed in entirety. The child's respiration became worse during the manipulations in this region and fairly marked cyanosis developed. As soon as the tumor was removed, however, the breathing improved and the child recovered rapidly. After careful control of bleeding the mediastinal pleura was closed with continuous catgut sutures. The muscles were stitched with single and continuous catgut sutures. Two hundred thousand units of penicillin were introduced into the pleural cavity. Fluid and blood were given intravenously during the operation. A further 100,000 units of penicillin were injected daily the first few days after the operation and oxygen was administered in the usual way. Slight stridor persisted the first two days, but no signs of suffocation were seen. The child nursed fairly well the first day and after the fifth postoperative day it nursed quite normally. Citric acid milk was added to its diet. It increased steadily in weight from 5,800 Gm. the day of the operation to 6,145 Gm. two weeks later, when it was discharged healthy and well healed.

Microscopic examination of the monocystic, goose-egg-sized mediastinal tumor showed a cyst lined partly with nonspecific granulation tissue and partly with mucosa. The latter was of pure blue color in some places and covered by epithelium of the simple columnar type with small glandular crypts like those seen in the mucous membrane of the colon. In one large region, it was of the highly differentiated type with pavement cells like that found in the fundus ventriculi. A large number of lymphoid areas were scattered over the mucosa. Beneath was a thin, regular, muscularis mucosae and a loose submucosa with small groups of unicellular glands. The most superficial layer of the wall was composed of a fairly regular, double-layered muscularis. The whole tumor was well defined. Nothing malignant was seen. The histologic diagnosis was enterocystoma with gastric mucosa heterotopia.

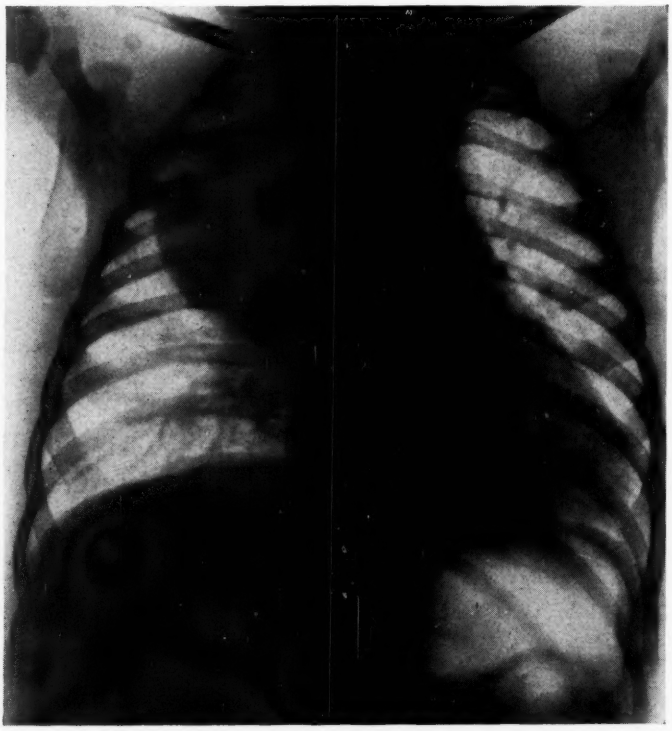

Fig. 1.—Girl 7 months of age, June 4, 1946. Orange-sized tumor in right pulmonary field originating in posterior mediastinum.

On re-examination three months after the operation the condition was quite normal. The child had increased rapidly in weight, now weighing more than 7,000 Gm. and x-ray examination showed fully normal conditions in the thorax (Figs. 3 and 4). The child had been completely healthy the entire intervening time.

COMMENT

Cystic formations of congenital origin, enterocystomas, occurring at different places along the alimentary tract and nearly always immediately adjoining it, are not particularly uncommon. They are lined with different forms

of mucous membrane, representing different locations in the alimentary tract. The type of mucous membrane lining a cyst need not correspond with the part of the alimentary tract where the cyst is situated or with which it is intimately connected. It is also interesting from a surgical standpoint that the muscular layers coating the cyst are often adherent to and sometimes comprise an integral part, microscopically, of the muscularis mucosae of the alimentary tract.

Fig. 2.—Lateral view demonstrating severe compression of trachea and right bronchus, which is displaced forward by the tumor.

As a rule, the cysts are well delimited from the actual lumen of the digestive tract. Sometimes, however, there is a direct communication. It is because of these two alternatives that the cyst sometimes contains the same matter as the alimentary tract and other times a nonspecific watery fluid or fluid containing hydrochloric acid and pepsin.

About eighty cases of intrathoracic cysts (Olenik a. Tandatnick) lined with alimentary tract mucosa have now been reported in the literature. Forty of these cysts were mediastinal and lined with esophageal, gastric, or enteric

mucosa. Some of the cysts were lined with only one form of mucosa and others with a mixture of types. The cysts lined with esophageal mucosa, twelve in number, do not appear to have endangered the life of the patients, at least in early years. Most of them were small and in an invulnerable position. One of the twenty-eight subjects with mediastinal cysts lined with gastric or intestinal mucosa was stillborn, five lived only a few hours after birth, and the oldest was only 3 years and 9 months of age. The only exception was the case reported by Adams and Thornton, of a 54-year-old man with a bronchoesophageal cyst. It is thus obvious that mediastinal cysts of foregut origin are of great danger to life, as a rule, and lead rapidly to death.

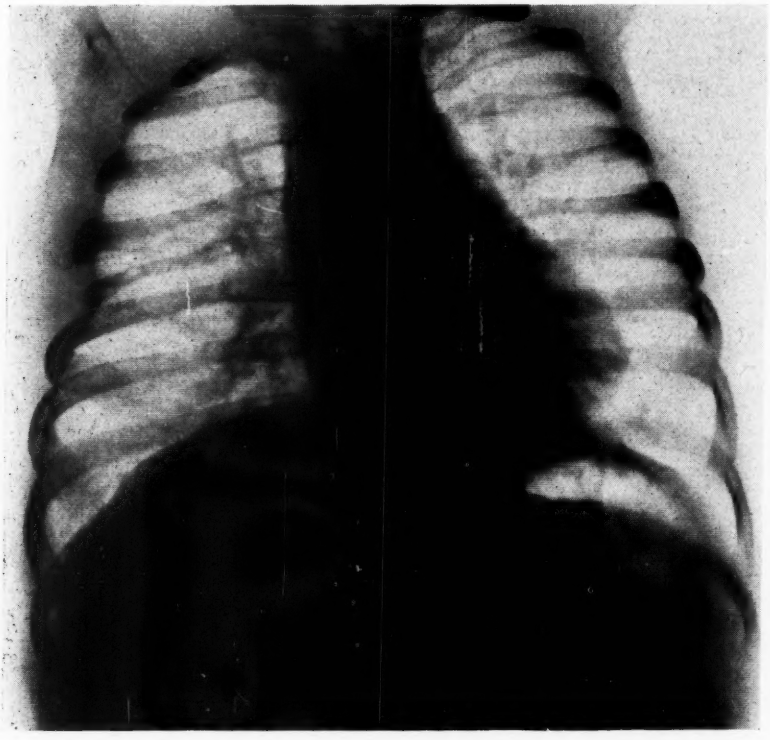

Fig. 3.—Sept. 26, 1946, three months after operation. Normal lung and heart puncture. The excised rib is now rebuilt.

The commonest situation for these intrathoracic enterocystomas is in the posterior mediastinum, often in fairly intimate contact with the pulmonary hilus. The esophageal cysts, however, often lie close to or within the wall of the esophagus. Thus, attempts to excise these cysts involve a risk of injury to the esophagus and dangerous complications. The intrathoracic enterocystomas occur for the most part on the right of the midline.

Seventeen patients of the forty published cases have been subjected to surgical treatment. Nine of the patients survived the operation and recovered completely. It is well to know that enterocysts along the alimentary tract are frequently associated with other congenital deformities such as spina bifida, scoliosis, and hydrocephalus. A combination of this kind was observed in eighteen of the forty reported cases.

Fig. 4.—Lateral view after operation showing trachea of normal width and normal bronchi.

Symptomatology.—The case published here represents one clinical type as regards symptomatology. The pressure exerted by the cyst on the trachea and right bronchus caused the development of atelectasis and bronchopneumonia, and dangerous attacks of suffocation. It may also be that the secretion from the gastric mucosa of the cyst contributed to the acute symptoms of compression. It is known that peptic ulcers, even perforating ones, may develop in mediastinal cysts lined with gastric mucosa (C. Böss). There was no definite relationship between the attacks and meals in the present case, however, several of the attacks having occurred during the night.

Otherwise the symptoms from these mediastinal enterocysts can be traced to (1) direct mechanical pressure of the cyst on neighboring organs, such as

the blood vessels, heart, esophagus, trachea, and bronchi and (2) complications which rapidly increase the volume of the cyst, such as infection or hemorrhage.

Böss' case of peptic ulcer in a mediastinal cyst may be mentioned in this connection. The ulcer perforated into the right lower lobe and on an attempt to remove the cyst, the patient died on the operating table.

The symptoms caused by direct pressure are commonly dry cough and attacks of suffocation and the complications to which they give rise, bronchopneumonia and atelectasis, as in the present case. Several instances of the pressure on the esophagus and trachea causing hemorrhage from these organs have also been published. In about 25 per cent of the published cases the symptoms consisted of attacks of suffocation, the patient's condition being good or relatively good in the interval.

Diagnosis.—The diagnosis of mediastinal enterocystoma is easy to make, at least the main diagnosis mediastinal tumor or cyst. The diagnosis is generally made after complications have developed and led to a thorough examination of the thorax, particularly with the roentgen ray. There are also cases, however, in which the diagnosis has been made after an incidental roentgen examination. In the majority of cases, particularly when the cyst has reached any size, roentgen study of the thorax gives a good idea of the state of affairs. In other cases, again, the diagnosis is difficult or impossible to make preoperatively (e.g. Olenik's and Tandatnick's case).

Obviously, roentgenographic examination is the most valuable guide to diagnosis. It is generally impossible to determine from the films whether it is a question of a cyst of enterogenous type or a dermoid. Sometimes, however, a dermoid cyst reveals its presence by exhibiting a fluid level (sedimentation phenomenon). It should be useful in cases of mediastinal tumors on the whole to inject contrast fluid in the esophagus and take planigraphic pictures to obtain a better idea of the tumor's location, tendency to compression, and so on. Other times, pneumothorax, combined with thoracoscopy, if necessary, may show the tumor's relation to the mediastinum and lungs. However, the latter forms of examination are unsuitable or entirely contraindicated in the case of children or infants.

Olenik and Tandatnick suggested transthoracic puncture with a fine aspirating needle as an additional guide to diagnosis. When fluid was found, they said, it could be aspirated and the cavity refilled with contrast medium. Personally, we believe that this is a highly unsuitable procedure. For one reason, it is our experience that operation (exploration after thoracotomy) is indicated in every case of mediastinal cyst. These cysts, however, are not seldom dermoids, and if the contents of these dermoids are spilled onto the pleura, severe irritation and pleurisy may develop. (We have previously operated on such a case.) Only in cases in which life-threatening compression of the trachea is present and operation cannot be done immediately by an expert thoracic surgeon, is there any justification for this form of intervention. Still other objections can be made to such an operation. One of us (H. B. W.) recently operated on a 4-year-old child with a so-called mediastinal tumor with almost the same roentgenographic appearance as the present one. Operation revealed a large cavern-

ous hemangioma with paper-thin walls in the hilus. Puncture of such a hemangioma would have led to a large hemothorax and life-endangering complications. Expert roentgen examination, including fluoroscopy and planigraphic study, perhaps complemented with the injection of contrast fluid into the esophagus, should be enough in most cases to give as exact a preoperative diagnosis as is possible, or, at any rate, one exact enough for surgical intervention.

Treatment.—As mentioned, mediastinal cysts and mediastinal tumors on the whole sooner or later give rise to complications, often of severe nature. Certain types of these cysts permit their bearer a life span of only a few days or months. Others, particularly the esophageal cysts, give rise to little or no complications, at least in early years. The cases of mediastinal cysts published hitherto give sufficient evidence of the great danger to life which they incur, and other mediastinal tumors seem to be equally dangerous (Crafoord a. Lindgren). Thus, operation should be indicated, not only in the case of acute complications during the first few months of life, but also in every case where the development of complications or incidental or routine roentgen examination shows that a mediastinal formation is probably or undoubtedly present. The early age at which these tumors are generally discovered is only of advantage as far as operation is concerned, though it is best to wait until after the end of the first year. In some cases, however, it may be necessary to operate during the first few months, though it may be difficult to determine this from the history. That it is possible to do this operation successfully is seen from cases published during recent years, such as the operations for tracheo-esophageal fistulas according to Haight and others.

The choice of the anesthesia is naturally of great importance in the case of infants of a few days to a few months of age. Intubation is probably necessary when it is a question of compression of the trachea and bronchi. A fine rubber catheter is generally sufficient for this purpose, if used in connection with the positive pressure method or "controlled respiration" according to Crafoord.

The best approach to the field of operation in most cases is that used for pneumonectomy. In infants, the removal of one rib, the fourth or fifth, is enough to give excellent access to the thoracic cavity and to allow a complete survey, at least of the superior region where these tumors are most often situated. As in the case of other benign mediastinal tumors, a good method is to make a small split in the mediastinal pleura and then use mainly blunt dissection for getting at the tumor.

No drainage has been used for the patients with mediastinal tumor operated on by us. Obviously, careful provisions must be made for stopping the flow of blood, and the use of penicillin is likewise a good precautionary measure.

SUMMARY

Widened experience with intrathoracic operations has shown that these operations may be done successfully even in the case of newborn infants (Gross, Haight, and others). This fact greatly improves the prospects of sucessful

surgical intervention for mediastinal tumors. There is no question that operations of this kind in infancy, before any complications have had time to develop, are easier to perform technically than in later years, and likewise that young children stand them better than old subjects. In the absence of definite contraindications, therefore, mediastinal tumors should be removed as soon as they are discovered, before complications necessitating an immediate and more perilous operation have developed. A case of mediastinal enterocystoma in a 7-month-old child causing acute and life-endangering tracheal compression—successfully operated on—demonstrates the logic of the above statements.

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THE TREATMENT OF THORACOGASTRIC FISTULA

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A FISTULA between the stomach and the left pleural cavity or chest wall may develop spontaneously as the result of perforation in a peptic ulcer or cancer, either when the stomach is in normal intra-abdominal position[1] or, more frequently, when the stomach is herniated into the thoracic cavity.[2-5] A thoracogastric fistula may also develop acutely as a complication of wounds involving the diaphragm and stomach.[6] Rarely, a thoracogastric fistula results from ill-advised surgical intervention when the existence of a diaphragmatic hernia with incarcerated stomach or eventration[7] is not recognized, and the surgeon at fault performs an intercostal trocar-catheter drainage, under the misapprehension that a pleural effusion or empyema exists. The present authors have had an unusual opportunity to treat two cases, in both of which the original surgical attendants had unwittingly inserted intercostal drainage tubes into herniated stomach. Serious complications developed, as might be anticipated. The recognition and management of these form the subject of this report.

It is considered timely to report these experiences now because diaphragmatic hernia is a well recognized, albeit uncommon, complication of military and civil trauma. Penetrating bullet and shrapnel wounds, as well as stab wounds, of the lower chest may involve the diaphragm and underlying viscera. Usually the situation will be recognized and corrected by early surgery, or the patient otherwise succumbs from peritonitis, pleuritis, or hemorrhage. Occasionally, however, a projectile or cutting instrument may so injure the diaphragm as to permit survival of the patient but with the subsequent herniation of intact stomach or bowel. One must then anticipate the development of complications which include obstruction or strangulation of intestine, and perforating or bleeding ulcers of the stomach. It is less widely recognized that blunt trauma to the chest and upper abdomen or a squeezing type of injury may, by indirect "bursting" violence to the diaphragm (particularly on the relatively unprotected left side), cause a laceration to appear in the thin central portion, sometimes extending into a normal hiatus, commonly the esophageal. Such lesions are easily overlooked in the period of acute reaction to trauma, because of surgical shock, the existence of other more obvious external trauma, or the presence of an obscuring hemothorax on the affected side. It should be emphasized, as illustrated by our second case, that such a diaphragmatic rupture can occur in the absence of fractured ribs.

With the return to civil life of many thousands of war veterans who have suffered wounds or other trauma to the lower chest and upper abdomen, the possibility of diaphragmatic laceration and hernia must be kept in mind,

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especially when abnormal physical and roentgen-ray signs are present in the lower chest, and particularly if symptoms of gastric or intestinal dysfunction are associated. It is not the purpose of this paper to describe in detail these findings and symptoms, which has been done adequately and repeatedly by many previous writers. It is the purpose, rather, to demonstrate what damage can occur when the true diagnosis is not made apparent, and transthoracic catheter drainage of a herniated viscus has been carried out and to present a rationale for surgical repair of these lesions and the complications attendant on ill-advised drainage procedures.

In the two cases hereafter summarized, a period of several months elapsed from the time of the original trauma to the onset of the acute episodes which, in the opinion of the original surgeons, demanded trocar-catheter drainage. In the first instance, sufficient adherence between the herniated stomach and the parietal pleura had occurred in three months so that the introduction of a catheter through the eighth thoracic interspace into the stomach did not result in a massive pyopneumothorax. The subsequent thoracogastric fistula resulted in a digestive reaction on the chest wall, and the development of a peptic ulcer at the site of the drainage tube. The ulcer in turn caused erosion of an intercostal artery and resulted in massive hematemesis. This first case illustrates the development of localized complications when an adherent stomach prevents pneumothorax collapse and generalized empyema.

The second case was more disastrous. Because of an absence of sufficient adhesions between herniated stomach and parietal pleura, the introduction of the catheter resulted in a leak of gastric contents into the pleural cavity and a massive pyopneumothorax, the advent of acute infection being complicated by loss of fluid, protein, and electrolytes. This patient presented simultaneously the metabolic problems associated with a high gastrointestinal fistula, and the infectious and mechanical respiratory problems of a pyopneumothorax with collapsed lung.

TREATMENT

The treatment in the first case was in theory relatively simple; that is, wide thoracolaparotomy with a dissection of the adherent viscera, local resection of the ulcerated portion of the stomach and its repair, reduction of the herniated abdominal viscera, and repair of the diaphragm. In practice, the complicating factors were the extremely dense and diffuse adhesions, the impossibility of preventing some soilage when the ulcer was transected, and the failure to bring about rapid reexpansion of the totally and chronically collapsed left lung, after an operation lasting seven hours. Therefore, an empyema developed which was handled by thoracotomy drainage and subsequently limited Schede thoracoplasty. The end result was, however, satisfactory in all respects.

The treatment in the second case included the establishment of adequate drainage of the total empyema by rib resection and large-bore tube, together with the institution of abdominal jejunostomy for feeding, and constant intragastric suction by Levine tube to reduce the fistulous drainage into the pleural cavity. After a period of stabilization and supportive treatment, during which

it became apparent that the thoracogastric fistula would not close spontaneously, a direct thoracic approach to the hernia through the contaminated pleura was accepted as inevitable, although with some trepidation. The stomach was mobilized, the fistula was repaired, the hernia reduced, and the diaphragm closed. The visceral pleura was then decorticated to permit lung reexpansion and the chest closed with a thoracic suction tube in place. From this point on, the management was like that of any chronic empyema.

Certain technical points are considered to be of importance. First, the edges of the fistulous opening (i.e., ulcer) of the stomach wall should be excised to permit an accurate two- or three-layered inversion type of closure with interrupted silk. Second, in reducing the herniated viscus, the area of closure should be displaced well away from the diaphragmatic suture line. The interposition of omentum is desirable. Third, during the operation, constant suction should be applied to a stomach tube, previously introduced through the pharynx, and this kept in place postoperatively. Also, similar constant suction may be applied to a rectal tube, which facilitates reduction of the distended colon (as in Case I) after administration of prostigmin. Fourth, bacteriostatic chemotherapy is indicated. It is fair to assume that a satisfactory outcome in the second case could not have been expected without the aid of penicillin and sulfonamide bacteriostasis. Fifth, adequate provision should be made for blood and fluid replacement, and protein substitution therapy.

CASE REPORTS

CASE 1.—G. A. was a white man, 30 years old. He was admitted to New Haven Hospital on May 20, 1940, with a chief complaint of pain in the left lower chest, and vomiting of blood.

Six years before admission the patient was severely injured in an automobile accident, sustaining a fractured pelvis and fractured left ribs for which he was hospitalized elsewhere three months. On discharge, he complained of weakness, cough, and pain in the left chest. His physician diagnosed fluid in the left pleural cavity, "probably empyema," and the patient was rehospitalized in his home locale for the introduction of a catheter into the left chest. This resulted in the drainage of scant milky fluid. A dissecting infection of the chest wall resulted, which required counterincisions for drainage. The tube was removed, and the chest wall infection then healed.

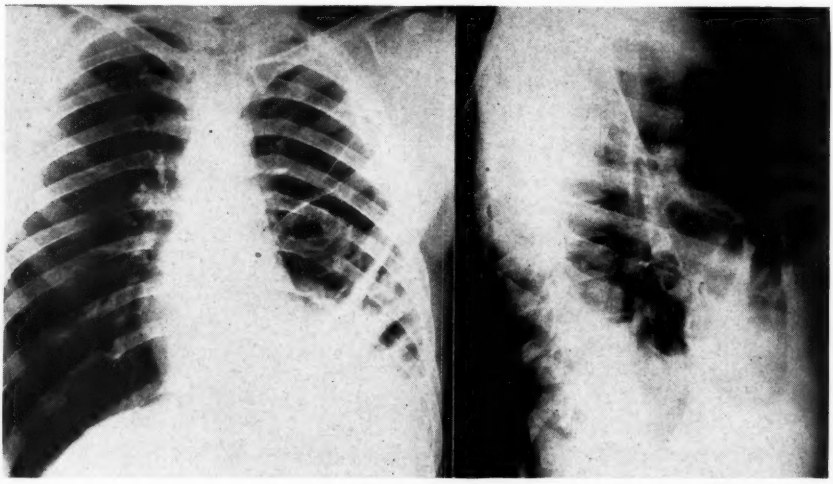
Thereafter he was relatively well until one year before admission, when he began to have increasingly severe left flank and left chest pain, made worse by exercise and by lying down quickly. On two occasions he vomited large amounts of bright red blood, was dizzy and weak, and subsequently had tarry stools.

On physical examination, the patient appeared thin and chronically ill. The temperature was 98.6° F., pulse 90, and respirations 20; the blood pressure was 110/90. The left chest was flattened, its respiratory excursions restricted, and there were two healed small scars in the subscapular region. There was percussion dullness at the left lung base posteriorly, and tympany over the left anterior chest below the nipple where peristaltic gurgles could be heard with a stethoscope. The left cardiac border could not be outlined nor the apex impulse felt. The abdomen was scaphoid and slightly tender to deep pressure in the left hypochondrium. The right lower extremity was 2 cm. shorter than the left.

Laboratory studies revealed a few white cells in the urine (first voided specimen), normal blood counts, and a fasting achlorhydria, with 22 units of free hydrochloric acid after histamin. The gastric specimens were positive for blood. The subtidal lung volume by the Christie method was 3,300 c.c. The antibrachial venous pressures were 106 and 103 mm. water respectively.

Roentgenograms of the chest on admission are reproduced in Fig. 1.

Operation was performed May 28, 1940. After induction of intratracheal cyclopropane-ether anaesthesia, the left chest was opened by resecting the sixth rib, and transecting the seventh and eighth. The pleural cavity contained densely adherent stomach, left colon, and many loops of small intestine. The large and small intestines were reduced first through an existing defect in the central, tendinous portion of the diaphragm extending into the esophageal hiatus. The stomach fundus, however, was densely adherent to the posterior parietal chest wall. At this site was a large gastric ulcer, the base of which was formed by the tissues of the eighth intercostal space, the intercostal artery being eroded. The gastric defect was repaired in three layers and the stomach returned to the peritoneal cavity. The diaphragmatic defect was closed in two layers with silk. The atelectatic lung failed to re-expand appreciably; the chest wall was closed in layers with silk.



A. *B.*

Fig. 1.—Case 1. *A*, Preoperative posteroanterior roentgenogram of chest, dated May 6, 1940. *B*, Preoperative lateral roentgenogram of chest, same date.

Postoperatively there was a low-grade fever. The pleural fluid was at first sterile but became positive for *Hemophilus influenza* and nonhemolytic streptococci. A thoracotomy and drainage resulted in return of temperature to normal and a smooth further convalescence. The empyema cavity was reduced in size to 100 c.c. In October, 1940, the patient was readmitted and a local Schede thoracoplasty completed the closure of the empyema sinus.

In January, 1943, the patient was well. The chest remained healed, and he was free of digestive symptoms. There was no roentgen evidence of recurrence of the hernia.

CASE 2.—W. B. was a 26-year-old white man. Five months before admission the patient was driving a car which crashed into a telephone pole, and he sustained an injury to his left chest. Roentgenograms of the chest were said not to reveal fractures of rib. Twelve days before admission, while at work carrying plaster, he began to have steady aching pain in the epigastrium and left hypochondrium, radiating later to the left chest. Soon after the onset of pain he vomited over a quart of bloody material. After admission to a hospital in a neighboring town, a roentgenogram of the chest (Fig. 2, *A*) was interpreted as showing fluid in the left pleural cavity. Thoracentesis was done with removal of a "half-gallon" of bloody fluid. His temperature thereafter rose to 106.8° F. Penicillin therapy was instituted with some

improvement, and four days later the physician inserted an intercostal catheter (Fig. 2, *B*) which drained profusely a coffee-colored fluid. His bowels did not move for five days prior to admission.

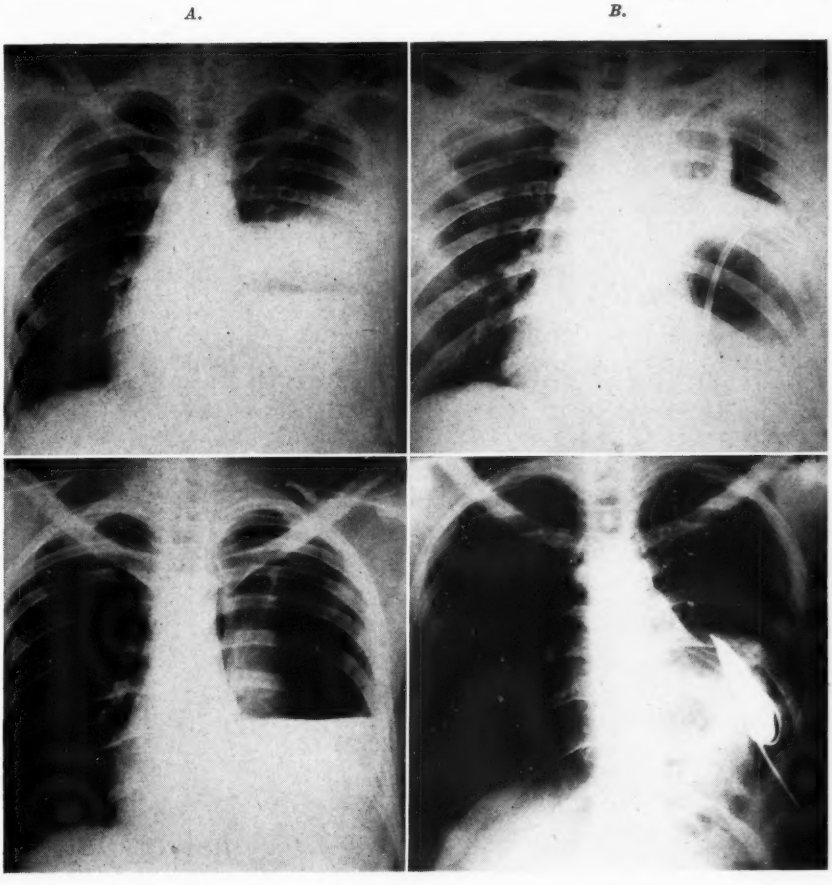


Fig. 2.—Case 2. *A*, Pre-admission roentgenogram taken Dec. 11, 1945. *B*, Pre-admission roentgenogram taken Dec. 12, 1945, after introduction of catheter. *C*, Roentgenogram taken Dec. 21, 1945, the day after admission. *D*, Lipiodol injection of residual empyema sinus, May 6, 1946.

On admission to this hospital on Dec. 20, 1945, the patient was desperately ill. The body temperature was 98.6° F., pulse rate 120, and blood pressure 100/50. There were confluent, pale reddish macules over the entire body. The left chest was hyperresonant, except for a flat area at the extreme base, and breath sounds were absent on this side. An intercostal catheter was present in the left midaxillary line. The white blood count was 16,100 with 89 per cent segmented neutrophiles. The serum protein was 6.1 Gm. per cent. The prothrombin level was 53 per cent of normal. Cultures of the drainage revealed hemolytic staphylococci, *Escherichii coli, Clostridium welchii* and *Streptococcus viridans.* The drainage fluid contained no free hydrochloric acid.

The roentgen findings on admission to this hospital are illustrated in Fig. 2, *C*. The left lung was almost totally collapsed with an adhesion at the apex. The mediastinum was shifted to the right. The transverse colon was displaced upward, and there was retained barium in the bowel.

A small amount of lipiodol was introduced into the esophagus and was seen fluoroscopically to enter the left pleural cavity, but its point of emergence was not determinable.

Treatment.—The dilating colon was decompressed by a cecostomy. On December 26, a portion of the left tenth rib was resected for introduction of a large drainage tube. On December 28, a jejunostomy was performed, and a limited upper abdominal exploration was carried out at this time. The stomach, as far as the pars media, seemed to be only in the subdiaphragmatic position, and the colon likewise.

Daily infusions of glucose and saline solution and citrated blood were given with sodium sulfadiazine. High caloric and high protein fluid feedings of larger volume caused diarrhea through the cecostomy. Chest irrigations were carried out daily with normal saline and aqueous azochloramid. The daily elevation of temperature began to subside on the thirty-first day of hospitalization and reached normal in another week. A barium enema was then done and found negative. Barium by mouth appeared rapidly in the pleural cavity, and the actual stomach filling was slight.

On February 7 a transthoracic operation was performed after resection of the left ninth and tenth ribs. The pleura was markedly thickened and anatomic landmarks difficult to identify. There was a large defect of the gastric greater curvature and fundus through which the lesser curvature mucosa was prolapsed. The diaphragm was incised to permit mobilization of the stomach. The gastric defect was repaired with an internal layer of catgut and external layers of silk. After reduction of the stomach, the diaphragm was repaired with interrupted silk sutures. The fibrinous surface of the visceral pleura was then incised and a good cleavage plane obtained for decortication. The patient was given 4,000 c.c. of citrated whole blood during the operation and was in good condition at the conclusion. Constant suction was applied to the chest drainage tube till the eleventh postoperative day.

Jejunostomy feedings were resumed on the second day after the return of peristaltic activity. Bedside chest film showed partial reexpansion of the left lung. The serum total protein was 4.5 Gm. on the second postoperative day, but rose to 5.5 Gm. three days later. The jejunal feedings were supplemented with 1,000 c.c. of 10 per cent amigen solution for several days. Oral fluid was begun on the sixth day but not taken well till the second week. From this time the course was one of steady progress, with discharge on May 8, 1946, at which time the cecostomy and jejunostomy had healed, and the diet was normal. The chest empyema sinus was located anterolaterally with a capacity of 60 c.c. Later plastic closure may be required. (Fig. 2, *D*.)

SUMMARY

1. Three distinct modes of origin for thoracogastric fistulas are described.

2. Two cases are summarized in which thoracogastric fistulas resulted from previous ill-advised intercostal catheter drainage of herniated stomach.

3. The complications of this misdiagnosis and therapeutic contretemps are discussed, and reparative methods are outlined.

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DISCUSSION

DR. RICHARD H. MEADE, JR., Chicago, Ill.—I might say that we had two patients, at Kennedy who had been aspirated overseas with the wrong diagnosis of pleural effusion. Fortunately, they were not cases in which bad results occurred. They were sent to us with diagnoses of diaphragmatic hernia.

DR. G. E. LINDSKOG.—I think that perhaps the proper place to present a communication of this sort is in a group of general medical men rather than specialized surgeons, because obviously the members of a society like this do not need to have it called to their attention. It is an error that can be made by the unwary with not too much difficulty.

With the large numbers of post-traumatic cases coming back, as mentioned in the previous discussor's paper, we have to bear in mind the possibility of additional cases of this type coming for treatment, and I hope that what we have given here will be of some help in the management of such problems.

I have heard of a third case which occurred in the Philippines. The patient was handled in a forward area. A catheter was put into the chest, and he was returned to a base where he died twelve days after the introduction of the tube.

CONGENITAL EVENTRATION OF THE DIAPHRAGM

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EVENTRATION of the diaphragm may be defined as an abnormally high or elevated position of one leaf of the intact diaphragm as a result of paralysis, aplasia, or atrophy of varying degree of the muscle fibers. Its unbroken continuity differentiates it from diaphragmatic hernia. If given the broad interpretation of some authors, the term eventration includes those conditions which follow surgical interruption of the phrenic nerve or involvement of it by trauma, inflammation, or neoplasm. Other authors would restrict the use of the term to cases of congenital and idiopathic origin. And it is this more limited interpretation with which this presentation will deal.

The condition occurs, or rather, has been observed at all ages and is assumed to be both acquired and congenital. Although this writing is concerned primarily with the lesion in infancy, some reference to the subject as a whole is included.

Bibliographers have credited Petit with the first description of the condition. A case report with post-mortem findings appeared in the posthumous edition of his work published in 1774. Infrequently thereafter, isolated cases were reported, and in 1913 Bergman reviewed the literature to that date and collected thirty-one cases. Three years later Bayne-Jones reported a collection of forty-five cases including one of his own. In 1921, Korns was able to assemble sixty-five cases, and in the most recent collection Reed and Borden, in 1935, reported 183 cases. Most of those were adults.

The etiology is obscure. Probably most cases are congenital and although present at birth may give no symptoms at the time and be discovered in childhood or adult life as an incidental finding or as a cause of symptoms. Some authors believe that in most instances the lesions are not anomalous but rather the result of injury to the phrenic nerve at birth. There is, however, good evidence that in some cases malformation is a factor. First, there are often present other malformations, and second, in some cases the diaphragm, although elevated, retains some degree of normal motion in contrast to the paradoxical movement of the paralyzed diaphragm.

During the present war an opportunity was afforded at the induction centers to observe congenital defects in large numbers. Majors Kinzer and Cook reported that during the examination of the roentgenograms of the chest of 412,149 inductees, they found thirty-five cases of congenital idiopathic eventration of the diaphragm. In all of these patients the lesion was entirely or relatively asymptomatic.

In an attempt to explain eventration on an embryologic basis, Cutler and Cooper suggested that the preponderance of the involvement of the left leaf

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of the diaphragm was related not only to the protection of the right leaf by the liver but also to the distribution of the vascular elements during the early formation of the embryo. It was reasoned that the vascular concentration in the region of the right side of the diaphragm contributed to the strengthening and blocking of the pleuroperitoneal canal on that side, while the atrophy of the common cardinal vein on the left might contribute to the weakening of the left half of the diaphragm.

Reed and Borden have summarized the pathologic observations as reported in the literature. They found that the diaphragm has been variously described, but that there is no adequate and detailed picture in any of the reports, and microscopic study of sections is almost totally lacking. In all cases the diaphragm was found definitely and markedly elevated. In twenty-two patients who came to autopsy or operation, the diaphragm was a thin, translucent membrane and usually consisted of a layer of fibrous tissue containing some muscle fibers and in a few cases only a thin, aponeurotic sheet. Sailer and Rhein found numerous muscle fibers upon microscopic examination of tissue from the diaphragm which grossly appeared to be entirely fibrous. Others, as Benda and Motzfeldt, have reported lipomatous pseudohypertrophy and atrophy with fatty changes.

The phrenic nerve on the affected side has been described as reduced in size but containing normal fibers with no evidence of degeneration in the nerve trunk or its nuclei. Morrison reported nine patients in whom the nerve was involved in a mass of fibrous tissue.

Abnormal lobulation of the lung has been reported and in Korn's case there was aplasia of the lung. The heart and mediastinal structures always show varying degrees of displacement into the unaffected side.

Rosenfeld reported a case of inversion of the stomach ("upside down") in association with eventration of the left half of the diaphragm.

Several associated and unassociated malformations of other organs and parts of the body have been reported. Among these may be mentioned failure of rotation of the colon, megacolon, hypospadias, and harelip.

In several instances the eventration of the diaphragm has been an incidental finding in patients suffering from such diseases as peptic ulcer and pulmonary tuberculosis.

In the infant the symptoms of eventration of the diaphragm are those of respiratory embarrassment, dyspnea, and cyanosis. Since infants present such disparate symptoms, it is difficult to explain the congenital origin of the lesion in the adult patients, who, as a rule, have no symptoms or were free of symptoms until adult life. It may be that there are degrees of eventration or that the relaxation of the diaphragm is gradual and progressive. In the adult there are no characteristic symptoms. Often entirely asymptomatic, the condition is an accidental or incidental roentgenographic finding.

Reed and Borden have divided the symptoms complained of by the patients into four groups: respiratory, gastrointestinal, circulatory, and general. The gastrointestinal symptoms in order of frequency were: abdominal pain, vomiting, dyspepsia, constipation, nausea, belching, loss of appetite, diarrhea, pain

on swallowing, cramps, and heart burn. The respiratory symptoms were: dyspnea, pain in the chest, cough, and wheezing, and the cardiac symptoms were palpitation, cyanosis, and tachycardia.

The physical findings are inconstant except for an increased respiratory excursion of the ribs on the affected side. This results from the absence of the inhibiting effect of diaphragmatic excursion. This phenomenon, known as Hoover's or Korn's sign, is said to be a constant finding. There is dullness or tympany at the base of the chest posteriorly on the affected side depending upon the organs and the contents of the organs immediately underlying the diaphragm. Also there are the signs of displacement of the heart.

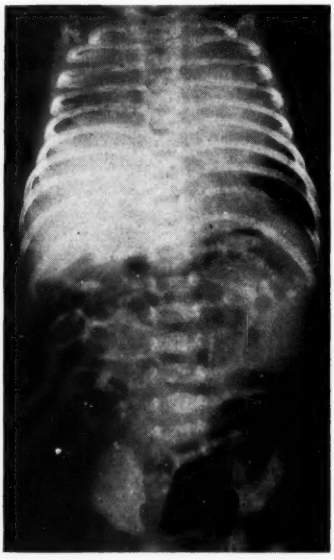

Fig. 1.—Preoperative film. The right diaphragm is elevated to the level of the posterior portion of the fifth rib and the heart and mediastinum are displaced to the left. The area of cardiac dullness extends to the left costal margin with only a small segment of unobscured lung in the left costal-phrenic sinus. The inferior margin of the liver is above the eleventh rib.

The diagnosis is made only upon roentgenographic evidence. The findings are quite typical; a conspicuous elevation of the diaphragm presents a smooth, unbroken curve. The entire diaphragm must be visualized so as to exclude hernia. This is usually possible by means of oblique and lateral views, fluoroscopic study, and the use of barium to outline the subphrenic structures. Motion of the diaphragm as observed fluoroscopically may be absent, but as a rule it is slight or paradoxical.

If in spite of these studies the differential diagnosis between diaphragmatic hernia and eventration remains in doubt, it has been suggested by Faulkner and others that pneumoperitoneum or pneumothorax be resorted to. This not

only outlines the diaphragm but in the case of a hernia, air may pass from one cavity to the other.

If the number of case reports is a criterion, eventration in infants is indeed a rarity. In his review of the literature up to 1916, Bayne-Jones collected three cases: a fetus, a new-born baby one day old, and an infant of 3 months. In each instance the diagnosis was made at post-mortem examination. In the literature from 1921 to 1935, Reed and Borden found reports of only five infants. From 1935 to 1946, at least nine additional cases in infants have been reported, including the one herein reported. Undoubtedly these figures give a very inaccurate conception of the incidence. In addition to the unreported cases it is very probable that some of the deaths in infants which have been attributed to other causes of cyanosis and dyspnea have, in reality, resulted from eventration.

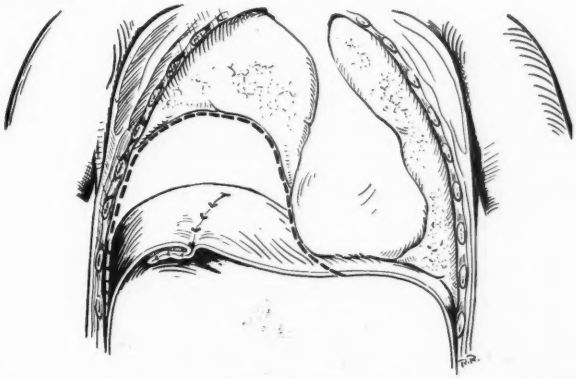

Fig. 2.—Diagrammatic representation of the position of the diaphragm (dotted line) and the resultant distortion of the intrathoracic viscera. This is also illustrated in the procedure used in the writer's case. Shortening was accomplished by plication with three superimposed rows of interrupted mattress sutures through an intrathoracic approach.

The writer's patient was unusual in that the right half of the diaphragm was involved. In the 183 patients of all ages whose cases were collected by Reed and Borden, only eighteen eventrations were on the right side.

As stated above, the symptoms in the infants, when recorded, were cyanosis and dyspnea, as in my case.

Direct operative attack upon the diaphragm has been done in only six cases. In all of them the diaphragm has been lowered by shortening, in one case by excision of a segment, and in five by plication. One was plicated from the abdominal side, the others from above through an intrathoracic exposure. One died three days after operation and the others obtained partial or complete relief of symptoms. The ages of these patients varied from 10 to 44 years.

So far as I am able to ascertain from a review of the available literature, my case is not only the first recorded instance of a surgical cure of this condition in an infant, but also the only record of operative intervention in a case in this age group.

CASE REPORT

Baby W., a male infant 6 weeks old, was brought to the Bishop Clarkson Memorial Hospital in an improvised oxygen chamber. He was born at full term without operative assistance and appeared normal at birth. On about the tenth day after birth the mother became impressed that respiration was somewhat labored and that cyanosis developed when the infant cried. Feeding became progressively more difficult and he failed to gain weight.

By the fifth week after birth the dyspnea and cyanosis had increased to such an alarming degree that it was necessary to administer oxygen. The father, who is an automobile mechanic in a rural community, fashioned a very satisfactory oxygen tent with the help of the family physician. Although the tent made survival possible, there was no improvement in the infant's condition after one week so he was brought to the hospital.

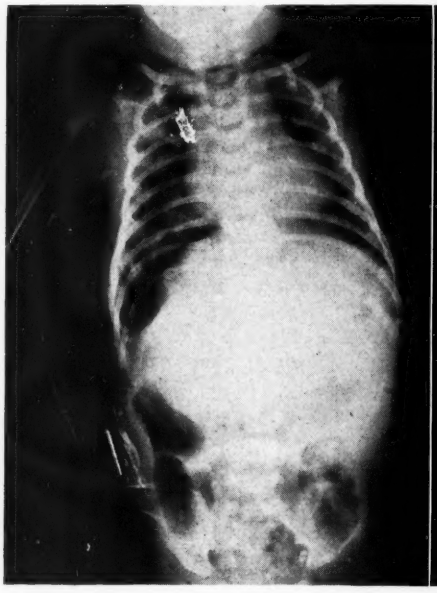

Fig. 3.

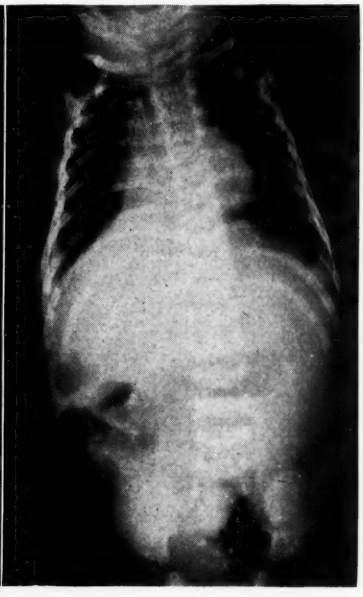

Fig. 4.

Fig. 3.—This roentgenogram, made immediately following operation, shows the right diaphragm lowered to a position below the left with complete aeration of both lungs and normal intrathoracic relations. The inferior border of the liver is several centimeters below the twelfth rib.

Fig. 4.—At the time of dismissal from the hospital, ten days after operation, the lowered position of the right diaphragm was still well retained.

Examination revealed a well-developed but poorly nourished infant of 6 weeks showing moderate dyspnea and rather marked cyanosis, both of which became very marked with crying and exertion. The right side of the chest moved less than the left, and there was lateral retraction with inspiration, also obvious use of the accessory muscles of respiration. There was dullness to percussion and absence of breath sounds below the level of the second rib anteriorly on the right side and in the upper two-thirds of the left chest. The liver was not palpable but the spleen extended 4 cm. below the left costal margin.

The weight was 6 pounds, 15 ounces, the temperature 97.2° F., the urine negative, the blood hemoglobin 12.7 Gm., and white blood cells 24,800, with 55 per cent segmented, 20 per cent staff forms, 5 per cent monocytes, 2 per cent eosinophiles and 18 per cent lymphocytes.

An x-ray film of the chest and abdomen (Fig. 1) showed the right diaphragm elevated to the level of the fourth rib posteriorly. There was increased density of the right lung, probably from compression, and an enlarged heart shadow which was displaced to the left to the extent that it was in contact with the left costal border. Evidence of aeration of the left lung was apparent at the inferior angle only. The liver shadow was displaced upward with its lower border above the costal margin.

A diagnosis of either eventration or hernia of the right diaphragm was made and surgical exploration undertaken July 29, 1944. Oxygen was administered with positive pressure through a mask in a closed system and the skin and underlying tissues of the right ninth intercostal space infiltrated with 0.5 per cent novocaine solution. Through this interspace the pleural cavity was opened and adequate exposure obtained with a small rib spreader.

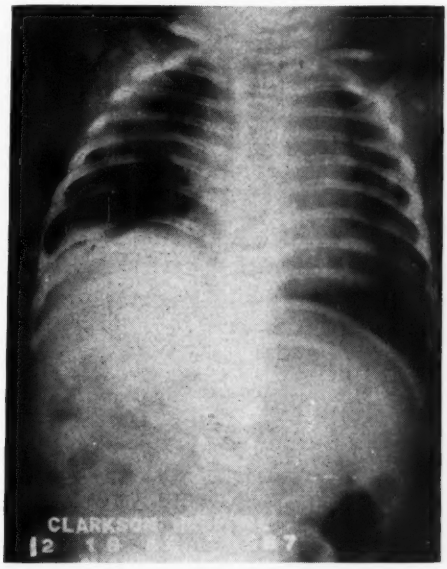

Fig. 5.—This roentgenogram made five months following operation shows the right diaphragm at the level of the ninth rib, one interspace higher than the left, presumably indicating that some giving way or relaxation has taken place. The writers are unable to explain the wedge-shaped shadow extending out from the right hilus and the broadened area of supracardiac density; possibly thymus. Note that the eighth and ninth ribs have become broader and fused as a result of the operative trauma.

The right diaphragm was intact throughout; that is, there was no break in its continuity. Its apex extended to the second rib anteriorly. Its excursion, though almost negligible, was not paradoxical. Except for pallor it appeared to be fairly normal and obviously it consisted of muscle. On casual observation there was no abnormality of the right lung.

The diaphragm was shortened and brought down to the level of the tenth rib by plication with three superimposed rows of interrupted mattress sutures of silk extending diagonally from the costal attachment in the region of the nipple line posteromesially to the aperture for the vena cava, as illustrated in Fig. 2. The pleat was turned downward between the diaphragm and liver. The chest wall was closed with pericostal sutures and silk was used in the muscle and skin.

There was complete relief of dyspnea and cyanosis immediately following operation and from then until the time of this report (twenty-two months after operation) respirations have continued to be normal. Also in every other respect the infant appears to be normal and is growing and gaining weight at a normal rate.

Roentgenograms of the chest immediately following operation and at periods subsequently are illustrated in Figs. 3, 4 and 5. It will be observed that with the return of the diaphragm to its normal position, the intrathoracic organs have likewise resumed their normal positions and both lungs are completely aerated. In the last roentgenogram the right diaphragm is one interspace higher than the left.

COMMENT

It is probable that the writer's case was more amenable to surgical therapy than most cases because the diaphragm contained muscle and had considerable substance in which the sutures were well retained against tension. Much less might be expected of cases in which the diaphragm is a very thin fibrous membrane, which apparently is the more common condition.

CONCLUSIONS

1. A successful operation and an apparent cure of eventration of the right diaphragm in an infant is reported.

2. As judged from reported cases, it is a relatively rare condition in infancy. The writer believes, however, that some infant deaths result from unrecognized eventration of the diaphragm.

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DISCUSSION

DR. H. BRODIE STEPHENS, San Francisco, Calif.—I believe the Association should congratulate Dr. Bisgard upon the excellent management of this interesting patient. There are two points I should like clarified, if possible, namely: (1) was the phrenic nerve demonstrated at the time of the operation, and (2) before surgery was the function of the right diaphragm observed under the fluoroscope?

DR. FELIX HUGHES.—We had one case of eventration of the diaphragm and I have a colored slide that I thought you might like to see.

(Slide.) This soldier had mild symptoms and we thought he probably had a diaphragmatic hernia. This photograph made at operation shows the high, thin diaphragm. There was no evidence of diaphragmatic contraction either at operation or on fluoroscopic examination before and after operation.

(Slide.) This shows the preoperative film on the left and the postoperative film on the right. The phrenic nerve was present but it was about one-half as large as a normal phrenic nerve. The diaphragm was cut so as to preserve the nerve and blood supply and sutured in an overlapping manner similar to a Mayo ventral hernia repair. The patient was returned to limited duty.

DR. BISGARD, Omaha, Neb.—I do not remember seeing the phrenic nerve in this case.

There was an attempted fluoroscopic examination before operation, but the child became very dyspneic and cyanotic out of the oxygen tent, and it seemed unwise to persist in fluoroscoping him. At operation there was very definite movement of the diaphragm in the right direction but it was only slight. Definitely, it was not paradoxical.

Subsequently he has been fluoroscoped; there is some motion of the diaphragm and it is not paradoxical.

In the literature they speak of the phrenic nerve being very small, smaller than normal in some of these cases. They suggest that in these cases it is the result of injury to the phrenic nerve at birth but, I am sure, both from visual observation at the time of operation and from study subsequently that the eventration in my case was not the paralytic type.

PULMONARY FUNCTION AFTER PNEUMONECTOMY AND LOBECTOMY

G. Birath, C. Crafoord, and P. Rudström
Stockholm, Sweden

PNEUMONECTOMIES and lobectomies are no longer unique operations, for, with the carefully worked-out methods now applied, they have become accepted as normal procedures for the treatment of malignant tumors in the lungs, and in connection with the treatment of bronchiectasis they have come to occupy an increasingly prominent place. These methods also have been applied in cases of pulmonary tuberculosis, although the indications there are not quite clear. In this connection there arises the question of whether or not the remaining lung tissue can carry on the respiration, a point of particular importance when considering operation upon older individuals whose lung function is reduced due to one cause or another, in which case operation may lead to complete respiratory insufficiency: it is of importance also when considering younger individuals, in whom, especially after pneumonectomy, the remaining lung tissue, overworked for many years, may conceivably become the seat of degenerative changes which impair the function, such as emphysema.

After pneumonectomy the remaining lung becomes enlarged, and fills the greater part of the thoracic cavity. The condition was observed by Haasler (1892) and afterward confirmed by a large number of researchers, among others Friedrich (1908), Möllgaard (1915), Giertz (1916), and Heuer and Dunn (1920).

This enlargement has been regarded as a so-called vicarious emphysema; but opinion is still divided as to whether a real emphysema in the anatomic sense, with atrophy and rupture of alveolar septa, develops, or whether the change amounts to a simple distension of the lung parenchyma, eventually in combination with hyperplasia. The question is, of course, of the greatest importance for the future function.

The results obtained in this respect depend, in the first place, upon whether the subjects operated on are still growing or adult. In the former case, experiments on animals seem to show that a real hyperplasia of the remaining parenchyma arises (Bremer, 1937). In adult animals, on the other hand, Bremer was not able to show regeneration or emphysema, but only a simple distension of the parenchyma. Rienhoff, Reichert, and Heuer (1935), who made a histologic examination of the remaining lung in ten dogs that had had pneumonectomy six months earlier, were also unable to find any emphysema, but only a simple distension. Behrend and Mann (1937) arrived at the same result in examination of dogs from eight days to eight years after the operation.

Phillips, Adams, and Hrdina (1941), on the other hand, also in connection with examination of dogs, showed that "marked compensatory emphysema with

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stretching and fragmentation of the alveolar walls occurs and persists in the remaining overdistended pulmonary tissue.'' These animals had lived for periods of up to three years after the operation, and in certain cases had been deprived of very large portions of the parenchyma. Longacre and Johansmann (1940), who examined both pups and adult dogs, found that the former adapted themselves well, whereas the latter showed signs of ''chronic emphysema, as seen in the breaking of the alveolar walls, thickening, and clubbing of their broken ends, collapse of capillaries, and possible fragmentation of elastic tissue.'' The animals had lived for periods of up to four years after the operation.

In seven cases of pneumonectomy performed on adult human beings who died from five days to one year after the operation, Rienhoff (1937) found no signs of emphysema.

In the light of the anatomic investigations adduced above, one cannot deny the possibility of an emphysema in the remaining lung tissue after pneumonectomy in adults, and the question then arises as to whether it has been possible to demonstrate it through reduced respiratory function.

The experimental investigations of the function after pneumonectomy and lobectomy are much fewer than the anatomic investigations that have been carried out. In close connection with this early observed enlargement of the lung we have Longacre's, Carter's, and Quill's (1937) investigation of the volume of the remaining lung in six pneumonectomized dogs. They employed Christie's (1932) method, and determined, among other things, the subtidal volume two, three, and six months after the operation. It was found that this lung volume first diminished but afterward increased, so that after four months it was practically as great as before the operation. At the same time, they investigated the oxygen saturation of the arterial blood, the body temperature, the frequency of the pulse, and the respiration while the animals were in a state of rest and after work on a treadmill. As Drastisch, Adams, Hastings, and Compere (1934) had done earlier, they found in this connection that the cardiorespiratory functional capacity was sufficient for rest and moderate work. An adaptation with improved function took place during the months immediately following the operation through increase of the tidal volume, subtidal volume, and amount of hemoglobin, in combination with a tendency toward increased arteriovenous oxygen difference with more intensive utilization of the oxygen of the arterial blood.

Longacre, Carter, and Quill (1937) also showed that the adaptation after pneumonectomy of three pups was so complete after nine months that it was not possible to demonstrate any difference as compared with the control animals. Three adult animals, on the other hand, showed marked reduction of function as compared with the control animals after the lapse of the same period following the operation. The investigation was carried out with the same methods as in the authors' earlier work (1937).

Good adaptation, though not so complete, was found by Lester, Cournand, and Riley (1942) in connection with the post-examination of three pneumonectomized children, 9, 12, and 14 years of age. In these they investigated the

total lung volume and its fractions, maximum breathing capacity and ventilation, breathing reserve, and respiratory gas-exchange under basal conditions as well as during and after work. The oxygen saturation of the arterial blood in the state of rest and after work was also investigated.

The maximum volume of the remaining lung proved to be less than the corresponding volume for both lungs of healthy control cases, but greater than for one lung alone. The residual air was 17.9, 26.7 and 16.0 per cent of the total capacity for the three cases respectively. The normal percentage was calculated as 20.4 per cent.

The remaining respiratory tests showed a constant reduction of breathing reserves. The case that showed the absolutely and relatively greatest residual capacity suffered the greatest loss of breathing reserves. It was not possible to demonstrate any definite change in the oxygen saturation of the arterial blood; the majority of tests were normal both in the state of rest and even after strenuous work.

The immediate change of blood gases (venous blood) and alveolar air after experimental pneumonectomy was studied by Heuer and Andrus (1922). They then found, besides certain temporary disturbances of the ventilation with accompanying changes of the alveolar air and blood gases, an increase of the oxygen capacity of the blood, which lasted throughout the period of observation (up to 66 days) and which was interpreted as a compensation phenomenon. The same observation, in principle, was also made by Edwards (1939) and Phillips, Adams, and Hrdina (1941).

Maier and Cournand (1943) made a study in human beings of the oxygen saturation of the arterial blood after resection of the lung, but they restricted themselves chiefly to the first postoperative period, finding during this a temporary reduction of the oxygen saturation.

Cournand and Berry (1942) investigated the cardiopulmonary function after pneumonectomy performed on twelve adult patients, mainly according to the same schema as Lester, Cournand, and Riley (1942) in the work already mentioned but with the addition of, among other things, "the pulmonary emptying rate," which constitutes "a numerical estimate of adequacy of inspired air distribution in alveoli."

The chief difference between patients with pneumonectomy and normal persons was "the reduction in their breathing reserve in various states of activity. This reduction, caused by a decrease in maximum breathing capacity, was greater in the older patients because of the cumulative effect of abnormal hyperventilation." This decrease in the maximum breathing capacity was not proportional to the diminished lung volume but was in a high degree dependent upon the state of the remaining lung. It proved that an overdistension of this lung was prejudicial for the function, and a subsequent thoracoplasty in four cases did not lead to any impairment of the function but was even of decided advantage. No cases with a long period of observation were presented so it was not possible to show emphysema resulting from the treatment. The authors pointed out, too, that the question had not yet been settled.

The function of the remaining lung tissue after pneumonectomy and lobectomy as regards the human subject, is in several respects, not yet clear. Experimental investigations (Paine 1940, among others) support the view that an emphysema which must gradually lead to impaired function may result from the distension of the remaining lung tissue that is unanimously considered to arise. Taking this as our point of departure, it has been our aim in the present investigation (1) to ascertain to what extent the remaining parenchyma is distended, and (2) by investigation of patients that for a longer period have been exposed to this distension, to attempt to show whether any impairment of the respiratory function occurs.

METHOD

Determination of the Total Lung Volume and Its Fractions.—For the determination of volume we have used the method earlier described by one of us (Birath, 1944). This method is based upon the principle propounded by van Slyke and Binger (1923), to let the patient, with ordinary, quiet respiration in a closed respiratory system, breathe a hydrogen-gas mixture whose volume and concentration, before and after the conclusion of the experiment, permits of the calculation of the amount of gas that has entered the lungs.

The procedure was as follows. The patient was examined in a comfortable sitting position in the morning on a fasting stomach, and after a rest of about half an hour. After determination of the vital capacity, the equilibrium capacity was investigated in the way described in principle above.* By taking samples of the gas mixture every minute it was possible to establish when the gas mixture was complete, that is, when the lung-volume values became constant. The mean value of at least three such values was taken as the definitive result of the lung volume. With this procedure a standard deviation for the single lung-volume determination amounting to 89 ± 19 c.c. was obtained with hydrogen-gas analysis according to the combustion method.

The relations between the different volume fractions have proved to be of particular value, especially the ratios $\frac{\text{equilibrium capacity}}{\text{total capacity}}$ and $\frac{\text{residual capacity}}{\text{total capacity}}$ It is known that the emphysema leads to a heightening of the latter ratio especially and that in this connection this ratio is a good exponent for the respiratory efficiency (Hurtado, Kaltreider, Fray, Brooks, and McCann, 1935). In systematic examinations of the volume relations in pulmonary tuberculosis, with and without collapse treatment as well as pneumonectomies and lobectomies, one of us (Birath, 1944) has been able to show that *a heightening of the relative lung volume values takes place in connection with impaired lung function, when there have arisen in the lungs air spaces which are inferior from the respiratory point of view* (emphysema, infiltrated or indurated lung parts, or other regions with reduced ventilation, lung distension in cases of bronchostenosis, and so on). As the normal value for the share of the residual capacity in the total capacity, the author found for men 22.7 per cent ± 2.5 and for women 25.5 per cent ± 2.8, while the corresponding figures for the equilibrium capacity were 48.4 per cent ± 5.0 and 46.3 per cent ± 6.0 respectively.

*Hutchinson's classification of the volume fractions of the lungs and Lindhard's nomenclature have been employed. According to the latter, a) the equilibrium capacity = the lung volume on expiration with the existing tidal volume; b) the residual capacity = the lung volume on maximum expiration; c) the total capacity = the lung volume on maximum inspiration.

It thus holds good not only for the emphysema, that the relations mentioned are a good exponent for the respiratory efficiency, for the rule seems to be valid also in respect of other pathologic states in the lungs. Here, then, is a possibility of judging the functional capacity of the parenchyma.

Determination of the respiratory dead space.—Especially in cases of emphysema it has proved that a measurement of the respiratory dead space may be of diagnostic value. It is often possible to determine this simultaneously with the lung volume according to a method that has been worked out by one of us (Birath 1944). The principle of the method is that the gas mixture in the spirometer system is followed with regular tests at intervals of exactly one minute. The rapidity with which the mixture takes place will depend upon, among other things, the dead space with which the lung ventilation takes place, and, as the other factors are known, the dead space can thus be calculated.

The values obtained from healthy persons with this method agree with values given earlier. In eleven determinations on eight men, the mean value obtained was 0.18 L.,* with variation between 0.13 and 0.26 L. The mean value for determinations of the dead space (D.S. value) carried out on five women was 0.11 L., with variation between 0.09 and 0.13 L.

The share of the D.S. value in the tidal volume (relative D.S. value) varied between 18 and 45 per cent, but was, as a rule, in the region of 30 per cent.

Thirteen cases of emphysema of different types (silicosis, bronchial asthma, essential emphysema) were all found, with the exception of two relatively mild silicosis cases, to have a D.S. value of 0.26 L. or more. In all of the cases except the two mentioned above, and one other case, the relative value was over 50 per cent.

It is thus quite clear that the dead space in emphysema patients increases both absolutely and relatively, and one thus has reason to expect that at least the pneumonectomies, and possibly also the lobectomies, in the degree in which they are complicated with emphysema, will show changed D.S. values.

Other Examinations.—The patients have also been subjected to a general examination, including x-ray examination of the lungs, physical examination of the heart and lungs, determination of blood pressure, and, in several cases electrocardiograms. Arterial puncture in the state of rest, with determination of the blood gases, has been carried out in eighteen cases.

Very carefully controlled data concerning the patients' dyspnea and working capacity have also been recorded.

MATERIAL

The patients examined comprise twelve pneumonectomized and fourteen lobectomized persons (eleven women and fifteen men) who were operated upon in the Sabbatsberg Hospital between two and thirteen years ago. The majority have been operated upon more recently, as may be seen from Table I. Most of the pneumonectomies were carried out on account of malignant tumours in the lungs, while the lobectomies, in part on account of bronchiectasis,

*All volumes are given at body temperature, saturated with water vapor, and at the prevailing Barometric pressure.

TABLE I. YEARS BETWEEN OPERATION AND EXAMINATION

OPERATION	YEARS											
	2	3	4	5	6	7	8	9	10	11	12	13
Pneumonectomies	5	3	1	—	—	2	—	1	—	—	—	—
Lobectomies	1	4	3	—	2	—	2	1	—	—	—	1
Total	6	7	4	—	2	2	2	2	—	—	—	1

TABLE II. DISTRIBUTION OF MATERIAL IN AGE GROUPS

OPERATION	AGE IN YEARS					
	10-19	20-29	30-39	40-49	50-59	60-69
Pneumonectomies			1	4	5	2
Lobectomies	1	2	3	2	4	2
Total	1	2	4	6	9	4

were performed on somewhat younger individuals (Table II). Only one of the cases, Ly-n, was operated upon as a growing individual, the others as adults. (Data concerning the cases may be found in Table X).

On x-ray examination the cases of lobectomy as a rule showed only slight pleuritic sequelae with obliteration of the costophrenic sulcus and pleural thickening, but in one patient also a pronounced pleural retraction was found (A.E-n); in W-n and W-t, bronchiectases were found in the remaining upper lobe, and in Be-n, remains of an encysted exudate on the operated side.

The pneumonectomy patients showed the usual x-ray picture with enlarged remaining lung and retraction of the heart and mediastinum to the operated side. In several cases there was in addition a so-called pulmonary herniation with sac-shaped bellying of the remaining lung into the opposite "lung area" in the region of the upper mediastinum (K-g, S-n, Lj-n, A-g, J.J-n, and W-t). Especially in these patients one could frequently hear respiratory sounds interscapularly on the operated side, which thus constitutes a physical symptom of the above-mentioned herniation.

Physical examination of the heart was also carried out, but with the dislocation of the organs in the thorax that results especially from a pneumonectomy, it is not easy to judge the results of this examination. In three patients, however, the heart sounds were dull, and in a few other patients the electrocardiogram or the blood pressure indicated the possibility or the existence of a cardiac lesion. In at least a couple of the cases this lesion was probably a contributory cause of the dyspnea (W-t, E.E-n). An analysis of the connection between the heart changes and the pulmonary situation does not fall within the scope of this paper, but is in itself an important task for research. Owing, among other reasons, to the varying states of the heart, one cannot, however, expect full correlation between the results obtained from the lung examinations and the patient's dyspnea.

RESULTS

1. *The Total Pulmonary Capacity and Its Subdivisions.*—It is clear that the total lung volume must be considerably reduced when one lung, or even only a lobe, is extirpated. When one investigates the magnitude of this reduction it might, on the face of it, appear most natural to take the preoperative

values as standards for comparison. Such a procedure, however, certainly is not right, since these preoperative values refer to pathologic conditions. Thus, it should be stressed that a bronchostenosis, for example, causes a considerable distension of the parenchyma situated distally to the stenosis. It entails, as in the case of general emphysema, altered relations between the different volume fractions. If a lung that has been distended in this way is removed, the cause of the pathologic increase of the residual and equilibrium capacities disappears. Thus, to compare the volume relations before and after the operation implies a study not only of the effect of pneumonectomy. It is therefore more correct to compare with individually calculated normal values, as we have done. The right lung in this connection has been calculated to amount to 53 per cent, and the left lung to 47 per cent of total volume (Björkman, 1934). The normal values have been calculated according to West (1920) on the basis of the area of the body surface.

One then finds that the total capacity is reduced, not so much as to correspond to the removal of the lung, yet less than that (Table III), for the empirical value for the remaining lung after a pneumonectomy proves to exceed the calculated value by about 0.40 L., that is, by nearly 15 per cent. Similar results were obtained by Cournand, and Berry (1942). This means that on maximum inspiration the lung is more strongly distended than ever before. This distension is not, however, excessive.

TABLE III. MEAN VALUES OF THE TOTAL PULMONARY CAPACITY AND ITS SUBDIVISIONS (ABSOLUTE VALUES) IN CASES OF PNEUMONECTOMY AND LOBECTOMY, COMPARED WITH CALCULATED VALUES FOR BOTH LUNGS

	ABSOLUTE VALUES (MEANS) LITERS (37° C., MOIST)							
	EQUILIBRIUM CAPACITY		RESIDUAL CAPACITY		VITAL CAPACITY		TOTAL CAPACITY	
OPERATION	FOUND	CALCULATED	FOUND	CALCULATED	FOUND	CALCULATED	FOUND	CALCULATED
Pneumonectomies (right) (7 cases)	1.94	2.88 (1.36)*	1.17	1.44 (0.68)	2.03	4.62 (2.18)	3.20	6.06 (2.80)
Pneumonectomies (left) (5 cases)	2.23	2.74 (1.45)	1.31	1.44 (0.76)	2.24	4.40 (2.33)	3.55	5.84 (3.10)
Lobectomies (14 cases)	2.11	2.67	1.19	1.38	2.60	4.29	3.79	5.66

*Parenthetical values refer to the *one* remaining lung.

But it is more important to ascertain whether, at its ordinary degree of distension corresponding to the respiratory midposition, the lung is more distended after pneumonectomy than before. If one compares the calculated and the empirical values for the lung volume in this position (Table III) one finds that the *equilibrium capacity* for the remaining lung, corresponding to the respiratory resting level, is approximately 50 per cent higher than before the operation. This increase in volume must be attained by a considerable distension of the parenchyma, which is about the same in right-sided and left-sided pneumonectomies.

The *vital capacity* is very slightly greater than the calculated value. This is in part due to the fact that the *residual capacity* considerably exceeds the

calculated values. In the explanation of this fact it is perhaps most natural to seek a purely mechanical factor, namely, the difficulty of reducing the space within the thorax on expiration to the point at which the calculated value of 0.7 to 0.8 L. is reached. Another possible explanation is that a moderate emphysema has arisen, which reflexly in the ordinary way gives rise to an inhibition of the expiration, and thus to a heightened residual capacity.

Owing to the above-mentioned circumstances, the relative lung volume values (Table IV) become more or less heightened, and thus also come to resemble decidedly the conditions in emphysema cases. The relatively large residual capacity might easily be explained by the above-mentioned mechanical thoracic factor, but the accompanying increase of the equilibrium capacity, which is surely not mechanically regulated, indicates that other factors such as reflexes from the circulation within the lungs play an active rôle. It is, in any case, worthy of note that Lester, Cournand, and Riley (1942), in their examination, of three pneumonectomized children, found approximately normal ratios for the share of the residual capacity in the total capacity. It is thus possible that in growing individuals an adaptation takes place in this respect. For the present, we must content ourselves with noting that the heightened ratios that have been shown here may be indications of emphysema.

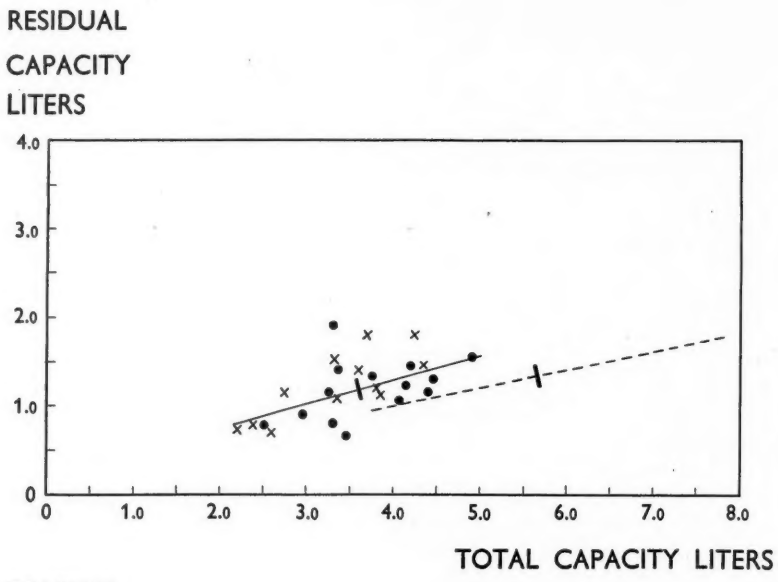
TABLE IV. MEAN VALUES OF EQUILIBRIUM CAPACITY AND RESIDUAL CAPACITY IN PER CENT OF THE TOTAL CAPACITY IN CASES OF PNEUMONECTOMY AND LOBECTOMY COMPARED WITH CALCULATED VALUES

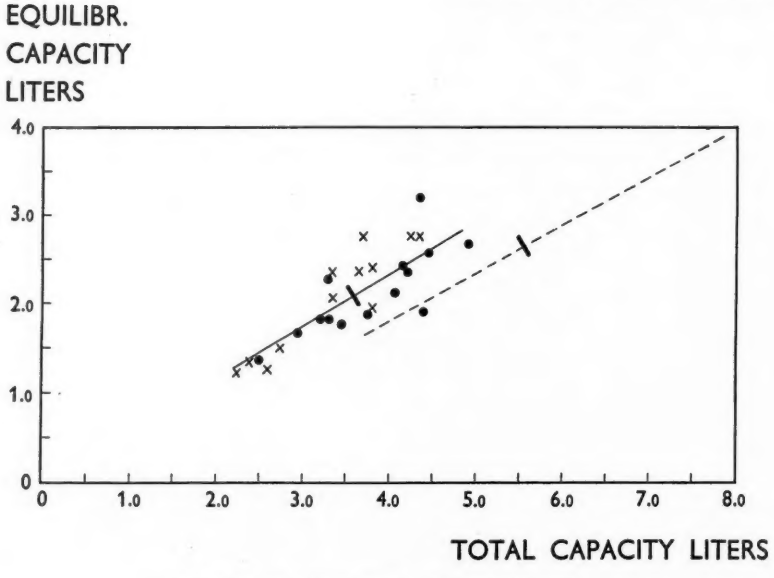
OPERATION	RELATIVE VALUES (PER CENT OF THE TOTAL CAPACITY—MEANS)			
	EQUILIBRIUM CAPACITY		RESIDUAL CAPACITY	
	FOUND	CALCULATED	FOUND	CALCULATED
Pneumonectomies (right) (7 cases)	60.7	47.5	36.6	23.7
Pneumonectomies (left) (5 cases)	62.8	46.9	36.9	24.6
Lobectomies (14 cases)	55.7	47.1	31.4	24.3

The conditions in lobectomy cases, as regards the absolute values, cannot be compared with calculated values as in pneumonectomy cases, since the extirpated lobes vary greatly in volume; but it must be assumed, and is, moreover, confirmed by the results as far as one can see, that the conditions are similar in principle, although less pronounced. Regarding the relative values (Table IV), one finds, as is to be expected, mean values lying between the normal values and those obtained for the pneumonectomies.

A statistical treatment of the results with covariance analysis (Bonnier and Tedin, 1940) shows that a statistically significant difference ($P < 0.001$) exists both for the ratio $\frac{\text{residual capacity}}{\text{total capacity}} \times 100$ and for $\frac{\text{equilibrium capacity}}{\text{total capacity}} \times 100$ as compared with a normal material examined earlier (Birath, 1944). (See Figs. 1 and 2.)

2. *Efficiency of the Lung Ventilation.*—A good insight into the ventilation of the remaining lung tissue is obtained from the dead space value. It proves that the ventilation, measured with this indicator, is always worse than under





Figs. 1 and 2.—*(For legend, see opposite page.)*

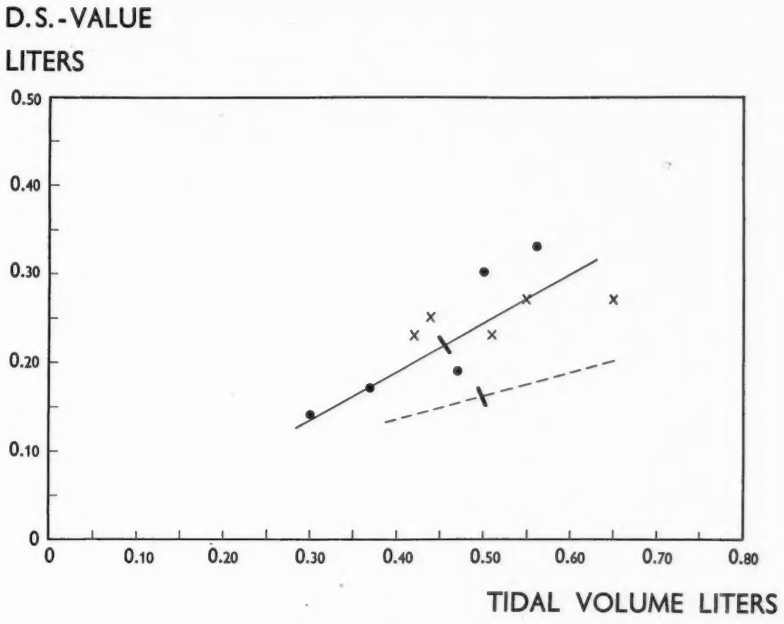


Fig. 3.—(*For legend, see below.*)

Fig. 1.—Relation between residual capacity and total capacity after pneumonectomy and lobectomy.

	Regression line and mean value	Regression equation	Regression coefficient	Correlation coefficient
Pneumonectomy cases (×) } Lobectomy cases (●) }	——/——	Y=O.2932X+O.1543	O.2932±O.2460	O.5995±O.1256
Normal cases (not plotted)	----/----	Y=O.2027X+O.2060	O.2027±O.0260	O.8034±O.0599

Fig. 2.—Relation between equilibrium capacity and total capacity after pneumonectomy and lobectomy.

	Regression line and mean value	Regression equation	Regression coefficient	Correlation coefficient
Pneumonectomy cases (×) } Lobectomy cases (●) }	——/——	Y=O.5981X–O.0560	O.5981±O.0805	O.8110±O.0671
Normal cases (not plotted)	----/----	Y=O.5451X–O.3940	O.5451±O.0495	O.8866±O.0362

Fig. 3.—Relation between D.S. value and tidal volume after pneumonectomy and lobectomy.

	Regression line and mean value	Regression equation	Regression coefficient	Correlation coefficient
Pneumonectomy cases (×) } Lobectomy cases (●) }	——/——	Y=O.5528X–O.0313	O.5528±O.1265	O.8240±O.0968
Normal cases (not plotted)	----/----	Y=O.2512X+O.0313	O.2512±O.1410	O.4903±O.2193

normal conditions. From Table V it appears that the mean value for the pneumonectomy cases is as high as 0.25 L. In the lobectomy cases there is a change in the same direction.

TABLE V. MEANS OF THE D.S. VALUE INDICATING THE VENTILATION EFFICIENCY IN CASES OF PNEUMONECTOMY AND LOBECTOMY

	ABSOLUTE VALUES (MEANS) LITERS (37° C., MOIST)		RELATIVE VALUES (MEANS)
OPERATION	D.S. VALUE	TIDAL VOLUME	$\frac{\text{D.S. VALUE}}{\text{TIDAL VOLUME}} \times 100$
Pneumonectomies (5 cases)	0.25	0.51	49.0
Lobectomies (6 cases)	0.20	0.42	46.8

Of still greater importance than the absolute D.S. values are the relative values (Table V). Here, too, one finds a considerable displacement in a pathologic direction, which perhaps is most pronounced after pneumonectomy, where the D.S. value constitutes, on the average, not less than 49 per cent of the tidal volume.

If with covariance analysis (Bonnier and Tedin, 1940) a statistical investigation of the difference as compared with a normal material (Birath, 1944) is carried out, one finds that the above-mentioned percentage increase of the D.S. value is statistically significant ($P < 0.001$). (See Fig. 3.)

The limitation of the method, which lies in the fact that the D.S. value can be calculated only in a certain number of the patients, namely, those in which the mixture between pulmonary air and spirometer gas takes place most slowly, entails to some extent a selection of the patients with the worst ventilation; but the same thing also holds good, of course, for the normal patients, and the existence of a difference is thus beyond doubt. On the other hand, in several of the patients in whom it has not been possible to determine the D.S. value, the conditions may be more favourable.

What is it, then, that causes this impaired ventilation? Half of the bronchial tree has been removed in the pneumonectomy patients, and herewith also a considerable part of the dead space, yet the D. S. value nevertheless increases in such a high degree. It cannot be due merely to a dilatation of the bronchi in the remaining lung tissue; the difference is too great to be explained in this way. On the other hand, there is a considerable distension of the finer structures in the lung, alveoli and alveolar ducts, which must hamper the mixing of the gases in a way in principle the same as in the case of emphysema, though in connection with the simple distension no atrophies arose. But that such atrophies (which is to say a real emphysema) may exist is very probable; but in all likelihood they are not a necessary condition for the impairment of the ventilation here established.

What has been shown here agrees well with what Haldane (Haldane and Priestley, 1935) has asserted in opposition to the Copenhagen school (Krogh and Lindhard, 1917), namely, that in connection with increased inflation of the lungs the respiratory dead space undergoes a considerable enlargement. That

this increase of the respiratory dead space arises in close connection with the operation through distension of the parenchyma and is not a late consequence of the same due to the development of an emphysema seems to emerge from a comparison with earlier investigations (Birath, 1944). The material does not permit of a definite decision as to whether any enlargement of the respiratory dead space comes about in the years after the operation, but a general comparison with the above-mentioned patients who were examined a short time after the operation shows no difference.

Now and then one finds in the literature an hypothesis that has been advanced by Verzár and Jeker (1936), among others, to the effect that there are reserves in the form of atelectatic alveoli in the lungs, which, when increased function is called for, are opened, thus enlarging the respiratory surface. It is very probable that if this reserve were of any considerable importance, the above-described increase of the respiratory dead space would not have arisen. The necessary reserves doubtless lie instead in an increase of the respiratory surface by the opening of capillaries covering the alveolar walls, that are collapsed in the state of rest (Wearn and associates 1934).

A possible cause of increased D.S. value that must be borne in mind is the varying ventilation in the lung, which has been shown to be able to give rise to such an increase (Birath, 1944). There is in general, however, scarcely any reason to expect any considerable increase of the unequal ventilation, or at all events not of that order of magnitude that would correspond to the heightened D.S. value. It is in bronchostenoses and local emphysemas or more considerable surface adhesions in the pleura that one must reckon with this cause of heightened D.S. value when there are no parenchymal changes giving rise to hypoventilation in their vicinity.

3. *Blood Gases.*—The blood gases have been examined only in the state of rest, and they show on an average normal values for the oxygen saturation (Table VI). Only one patient, W-l (Table X), shows a clearly reduced saturation. This was also the one that showed the highest relative value for the residual capacity, 56.6 per cent, and the highest relative D.S. value, 60.5 per cent. This patient was one of the most dyspneic. The cause of this poor function is, at least in part, bronchiectasis in the remaining right upper lobe, as well as reduced ventilation of the latter through pleuritic sequelae after the operation. In addition, he was subject to auricular fibrillation and impaired cardiac function for periods.

TABLE VI. MEAN VALUES OF BLOOD GASES AT REST IN CASES OF PNEUMONECTOMY AND LOBECTOMY

OPERATION	BLOOD GASES (MEAN VALUES)			
	VOL. % CO_2	VOL. % O_2	VOL. % O_2 CAPACITY	% O_2 SATURATION
Pneumonectomies (7 cases)	48.7	18.6	19.5	95.4
Lobectomies (11 cases)	45.8	17.9	18.6	96.2

As regards the oxygen capacity, no characteristic change can be said to occur, and the same applies as regards the carbon dioxide. The observations concerning the blood gases agree generally with those made by Cournand and Berry (1942) after pneumonectomy.

4. *Dyspnea.*—Of particular interest are the data concerning dyspnea given by the patients. During the first period after the operation the respiratory dynamic is considerably disturbed, due to the after-effects (pains, thoracic rigidity) of the operation. During this period dyspnea is often marked, but then gradually diminishes, and after the lapse of at least a year a stationary state has, in general, been reached. This improvement can also be followed in the lung volume determinations carried out on patients who have been regularly examined. Such examinations have already been described by one of us (Birath, 1944), and it is unnecessary to discuss them in detail here.

It should only be pointed out that this improvement finds expression both in an increase of the absolute values of the vital and eventually also the total capacity, and in a decrease of the relative lung volume values, the ratios between the residual and equilibrium capacities on the one hand and the total capacity on the other. A-g (Table VII) illustrates this development.

TABLE VII. REPEATED EXAMINATIONS OF THE PULMONARY CAPACITIES AFTER PNEUMONECTOMY IN A-g, NO COMPLICATIONS

TIME FOR EXAMINATION (MO. AFTER OPERATION)	ABSOLUTE VALUES LITERS (37° C., MOIST)				RELATIVE VALUES PER CENT OF TOTAL CAPACITY	
	EQUILIBRIUM CAPACITY	RESIDUAL CAPACITY	VITAL CAPACITY	TOTAL CAPACITY	EQUILIBRIUM CAPACITY	RESIDUAL CAPACITY
1	2.36	1.58	1.71	3.29	71.7	48.0
7	2.14	1.26	2.20	3.46	61.8	36.4
14	1.88	1.11	2.08	3.19	58.9	34.9
19	2.09	1.05	2.39	3.44	60.8	30.5
38	2.04	1.06	2.27	3.33	61.3	31.8

With some few exceptions the tendency to dyspnea after the postoperative period has been fairly constant, and has not increased with the years, which ought to be the case if any considerable emphysema had developed. In point of fact this is a very important indication against the suspicion of an emphysema of functional significance.

The patients, five in number, in which the dyspnea has clearly increased, are, in the main, to be explained on other grounds. One of these is Li-n, who had an exudative pleuritis on the left side six months after a right sided pneumonectomy. In connection herewith his total and vital capacities (Table VIII) decreased, instead of gradually increasing, as is otherwise the rule. No reduction of the relative lung volume values occurred (see Table VII); there was, instead, an increase, indicating an impaired ventilation in the remaining lung. Both the absolute and the relative increase of the D.S. value after the pleuritis is also an indication in the same direction.

Another pneumonectomy patient, E.E-n, has had a somewhat increased dyspnea and edema in the legs in the evening, at times, which, on account of certain symptoms from the heart and a blood pressure of 185/110 mm. Hg, indicate cardiac insufficiency.

TABLE VIII. REPEATED EXAMINATIONS OF THE PULMONARY CAPACITIES AND D.S. VALUE BEFORE AND AFTER PNEUMONECTOMY IN CASE LI-N 6 MONTHS AFTER OPERATION PLEURISY ON THE FUNCTIONING SIDE REDUCING THE PULMONARY CAPACITIES AND IMPAIRING THE VENTILATION

TIME FOR EXAMINATION	ABSOLUTE VALUES LITERS (37° C., MOIST)				RELATIVE VALUES PER CENT OF TOTAL CAPACITY		ABSOLUTE VALUES LITERS (37° C., MOIST)		RELATIVE VALUES PER CENT OF TIDAL VOLUME
	EQUILIBRIUM CAPACITY	RESIDUAL CAPACITY	VITAL CAPACITY	TOTAL CAPACITY	EQUILIBRIUM CAPACITY	RESIDUAL CAPACITY	D.S. VALUE	TIDAL VOLUME	D.S. VALUE
Before operation	3.96	2.42	5.03	7.45	53.2	32.5	0.26	0.60	43.3
1 month after operation	2.68	1.66	2.29	3.95	67.8	42.0	0.16	0.44	36.4
8 months after operation	2.30	1.53	1.99	3.52	65.3	43.5	---	---	---
28 months after operation	2.32	1.53	1.80	3.33	69.7	45.9	0.25	0.44	56.8

The remaining three patients who speak of somewhat increased dyspnea with the years are lobectomy cases. One of these is a woman, A-n, 62 years old, with hypertension of 200/160 (?) and suspected heart changes. Another is a 55-year-old man (W-l), who has had auricular fibrillation at times, so that there is reason to believe the heart to be the chief cause of the condition. In the third patient, a 55-year-old woman, F-g, no evident cause is to be found.

The other patients, as has already been mentioned, have had a fairly constant or a reduced tendency to dyspnea after the postoperative period. With the exception of those with increased dyspnea, all the lobectomy patients have been able to go up three to five flights of stairs in an ordinary house without stopping and without troublesome dyspnea. Several ride bicycles, have had confinements, and one has climbed a mountain of 1,000 m.

With the exception of two patients, the above-related pleuritis patient (Li-n) and another with cardiac changes (W-t), the pneumonectomy patients have been able to go up two to five flights of stairs without undue exertion, and a number of them ride a bicycle. One housewife (Lj-n) declares that she both scrubs floors and washes clothes, and a person who is fond of the open air (S-n) finds no particular difficulty in going for walks in the woods or across country.

With these data concerning dyspnea, it is not surprising that the great majority of the patients enjoy full or practically full working capacity, as is

TABLE IX. WORKING CAPACITY AFTER PNEUMONECTOMY AND LOBECTOMY

OPERATION	WORKING CAPACITY		
	FULL	HALF	NONE
Pneumonectomies	9	1	2
Lobectomies	14	-	-
Total	23	1	2

shown in Table IX. Exceptions are Li-n, described above, with pleuritis after the operation, F-n, who is unable to work on account of metastases, but whose pulmonary status is good, and W-t, who enjoys no more than one-half his working capacity, partly on account of heart changes. The rest, even including those who have become worse after the operation, do their work as usual.

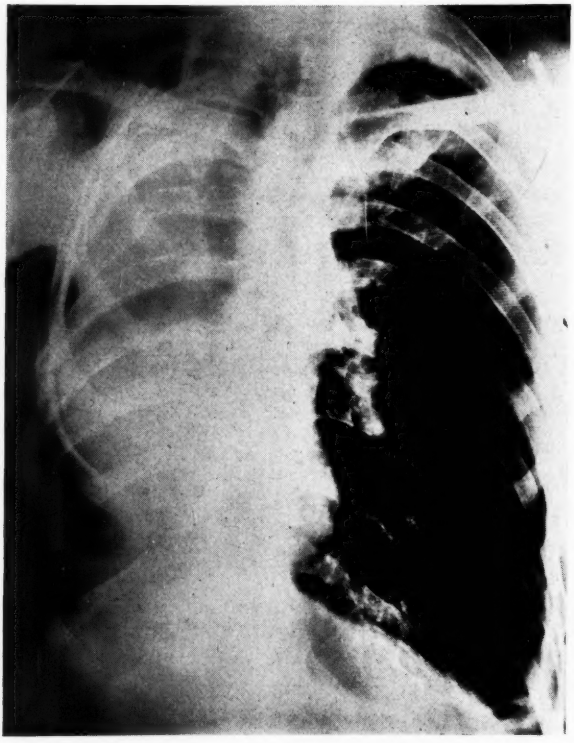


Fig. 4.—Li-n. Right-sided pneumonectomy. Six months after operation, pleurisy on the left side caused ventilatory insufficiency.

DISCUSSION

If we consider the values found for the lung volume and the dead space from case to case in respect of the tendency to dyspnea, we find in several cases a clear correlation, for the highest figures for the share of the residual capacity in the total capacity are found in the most dyspneic patients (W-t, Li-n, and W-l). It is also among the most dyspneic patients that we find the highest relative D.S. values (Li-n, W-l). Otherwise, of course, one cannot expect to find a very close agreement between the data concerning dyspnea given by the patients themselves and colored by their subjective estimation, and the values obtained for the lung volume and the dead space. Moreover, we have to reckon with other dyspnea-provoking factors than those investigated here,

especially those connected with the circulation. A good general condition and training of the organs of respiration and circulation doubtless also help to a certain extent to compensate defects in the function of the parenchyma of the lung.

It has emerged from this investigation that the relative lung volume values, which are a fairly reliable criterion of the respiratory efficiency, show, after pneumonectomy and lobectomy, a quite definite rise, indicating, like the heightened D.S. values, a reduced function of the measured lung volume. When in addition the parenchyma, especially in the pneumonectomy cases, is considerably reduced, one has reason to expect a rather strong tendency to dyspnea. In some cases one also finds this, but in uncomplicated cases compensation mechanisms evidently appear, perhaps chiefly in the form of increased circulation with a larger diffusion surface in the remaining parenchyma, and improve the situation. What, above all, must hinder this compensatory phenomenon is a reduction of the pulmonary vascular bed, as in connection with emphysema. It is also in these cases that one finds the worse results functionally after the operation (Cournand and Berry, 1942).

In operations performed on growing individuals there is a possibility of hyperplasia of the lung tissue, whereby the disadvantages of distension of the lung are eliminated. It is also interesting to note that the patient who had the lowest absolute and relative D.S. value of all examined, 0.09 L., 28 per cent of the tidal volume, was the only one that was operated upon before the subject had stopped growing.

Whether, there arises any emphysema in a pathoanatomical sense otherwise, among the adults, cannot be decided, but it is quite evident that in general there is no risk of progressive emphysema worth mentioning. So far we have performed a post-mortem examination of only one case where the patient had survived the operation for a long period. This was a 58-year-old man, who died two and one-half years after pneumonectomy. On post-mortem a slight but quite definite emphysema was found. It was not possible to decide, however, whether this emphysema had existed before the operation or not.

SUMMARY

Twelve patients after pneumonectomy and 14 after lobectomy have been investigated two to thirteen years after the operation, chiefly with the aim of ascertaining the extent of the lung distension and any possible reduction of function through emphysema.

The following methods have been used:

(a) determination of the total lung volume and its fractions, as well as the mutual relation between residual capacity and total capacity and equilibrium capacity and total capacity;

(b) determination of the efficiency of the ventilation by reference to the D.S. value (respiratory dead space);

(c) determination of the blood gases; and

(d) general clinical examination.

TABLE X.

CASE	SEX	AGE	HEIGHT	WEIGHT	YEARS AFTER OPERATION	PULMONARY CAPACITIES: ABSOLUTE VALUES LITERS (37° C. MOIST) EQUILIBR. CAPACITY	RESIDUAL CAPACITY	VITAL CAPACITY	TOTAL CAPACITY	PULMONARY CAPACITIES: RELATIVE VALUES PER CENT OF TOTAL CAPACITY EQUILIBR. CAPACITY	RESIDUAL CAPACITY	D.S. VALUE: ABSOLUTE VALUES LITERS (37° C., MOIST) D.S. VALUE	TIDAL VOLUME	D.S. VALUE: RELATIVE VALUES PER CENT OF TIDAL VOLUME
Right-Sided Pneumonectomies:														
W-t	♂	60	175	63	3	2.76	1.79	1.92	3.71	74.4	48.2	0.27	0.65	41.5
J. J-n	♂	45	168	65	3	2.75	1.47	2.89	4.36	63.1	33.7			
Ö-d	♂	46	171	65	2	1.36	0.78	1.62	2.40	56.7	32.5			
Li-n	♂	45	180	61	2	2.32	1.53	1.80	3.33	69.7	45.9	0.25	0.44	56.8
F-n	♂	63	181	72	2	1.93	1.21	2.58	3.79	50.9	31.9			
E. E-n	♀	38	171	74	7	1.26	0.69	1.90	2.59	48.7	26.6			
Lj-n	♀	50	161	55	2	1.22	0.73	1.50	2.23	54.7	32.7			
Left-Sided Pneumonectomies:														
S-n	♂	58	170	62	7	2.77	1.79	2.47	4.26	65.0	42.0	0.23	0.51	45.1
R-g	♀	44	176	65	9	2.40	1.16	2.63	3.79	63.3	30.6	0.23	0.42	54.8
Bo-n	♂	53	164	54	4	2.37	1.38	2.25	3.63	65.3	38.0	0.27	0.55	49.1
A-g	♀	50	157	58	3	2.04	1.06	2.27	3.33	61.3	31.8			
A. J-n	♂	55	176	84	2	1.56	1.16	1.58	2.74	56.9	42.3			
Lobectomies:														
Middle lobe and right lower lobe:														
Be-n	♂	51	163	71	9	1.86	1.34	2.42	3.76	49.5	35.6	0.33	0.56	58.9
Lower lobe:														
W-n	♂	52	182	79	4	3.19	1.41	3.19	4.37	73.0	32.3			
G-n	♀	34	168	64	3	2.67	1.54	3.35	4.89	54.6	31.5	0.17	0.37	45.9
Ly-n	♂	19	178	60	8	2.55	1.28	3.18	4.46	57.2	28.7	0.09	0.32	28.1
E-l	♂	40	174	68	4½	2.38	1.22	2.94	4.16	57.2	29.3	0.19	0.47	40.4
H-t	♂	62	173	64	4	2.37	1.48	2.73	4.21	56.3	35.2	0.14	0.30	46.7
W-l	♂	52	170	65	6	2.32	1.88	1.44	3.32	69.9	56.6	0.30	0.50	60.0
I-m	♀	34	160	58	3	2.10	1.04	3.02	4.06	51.7	25.6			
F-g	♀	55	153	62	3	1.80	0.79	2.53	3.32	54.2	23.8			
G-e	♀	23	161	54	2	1.73	0.66	2.77	3.43	50.4	19.2			
A. E-n	♀	28	158	54	3½	1.66	0.91	2.06	2.97	55.9	30.6			
O-n	♀	37	158	59	13	1.36	0.77	1.70	2.47	55.1	31.2			
Upper lobe:														
V. J-n	♂	45	164	74	6	1.79	1.15	3.26	4.41	40.6	26.1			
A-n	♀	62	160	72	8	1.79	1.13	2.11	3.24	55.2	34.9			

*+ = dyspnea on moderate exertion.
++ = dyspnea even on slight movement.
+++ = dyspnea even in the state of rest.
†Owing to carcinomatosis.
‡Had delivery.

CASE REPORTS

BLOOD GASES				CLINICAL DATA					
VOL. % CO_2	VOL. % O_2	VOL. % O_2 CAPACITY	% O_2 SATURATION	CYANOSIS AT REST	DYSPNEA*	PHYSICAL EXAMINATION OF THE HEART	ARTERIAL BLOOD PRESSURE, MM. HG	ELECTROCARDIOGRAM	WORKING CAPACITY
46.2	19.95	20.65	96.6	0	++	Dull heart sounds	120/80	P-R interval 0.22 sec.	½
48.2	18.5	19.4	95.4	0	(+)	0	120/90	Normal	1
46.5	18.3	19.2	95.3	0	(+)	0	110/90	Normal	1
51.6	16.9	17.6	96.0	0	+(+)	Dull heart sounds	120/90	---	0
				0	(+)	0	180/110	Neg. T_1 and isoelectric T_2	0†
				(+)	+	0	185/110	---	1
				0	+	Dull heart sounds	140/100	---	1
46.9	19.2	20.35	94.3	0	(+)	0	150/100	Neg. T_1	1
					(+)	0	150/?	---	1
				0	(+)	0	150/100	---	1
52.6	17.7	19.0	93.1	0	+	0	130/90	---	1
48.8	19.5	20.15	96.8	0	+	0	130/100	Deeply neg. P_3	1
				0	(+)	0	150/100	---	1
46.5	19.4	19.65	98.7	0	(+)	0	140/100	---	1
42.2	17.55	18.0	97.5	0	(+)	0	130/90	Normal	1‡
				0	(+)	0	110/80	---	1
49.2	18.15	19.05	95.3	0	+	0	130/90	Normal	1
45.5	19.35	20.75	93.3	0	-	0	130/100	Left axis deviation	1
49.0	16.2	18.2	89.0	0	+(+)	0	130/90	Sometimes auricular fibrillation	1
44.3	16.0	16.6	96.4	0	(+)	0	120/80	---	1
47.1	17.15	17.85	96.1	0	+	0	150/100	Normal	1
				0	(+)	0		---	1‡
43.5	18.0	18.45	97.6	0	(+)	0	145/95	---	1‡
45.2	17.5	17.6	99.4	0	(+)	0	140/100	---	1
45.3	19.5	20.7	94.2	0	(+)	0	150/110	Normal	1
46.5	17.55	18.2	96.4	0	+	0	200/160(?)	Normal	1

Results obtained:

1. In pneumonectomy patients the total lung volume is somewhat less reduced than the corresponding loss of parenchyma. In the position of maximum inspiration the remaining lung tissue (probably also in the lobectomy cases) is, therefore, exposed to increased distension.

2. The distension of the lung tissue is especially marked in the respiratory midposition, for in the equilibrium position the lung volume is approximately 50 per cent greater after pneumonectomy than calculated.

3. The share of the residual and equilibrium capacities respectively in the total capacity is clearly increased, both after pneumonectomy and after lobectomy. This indicates a qualitative inferiority of the measured lung volume, a reduction of the respiratory efficiency.

4. Through pneumonectomy and lobectomy the lung ventilation has worsened conditions, with, both absolutely and relatively (in relation to the tidal volume), an increased value of the respiratory dead space. This is probably very largely due to the increased lung inflation, possibly to a certain extent to emphysema.

5. The blood gases in the state of rest show no changes as a rule.

6. After pneumonectomy and lobectomy, dyspnea is, as a rule (in uncomplicated cases) stationary and not progressive after the postoperative period, during which, however, it steadily diminishes. It is in many cases surprising how little the subject is troubled by it. The working capacity in twenty-three of the twenty-six patients was full.

7. If after pneumonectomy or lobectomy an emphysema develops in the course of the years, which is not improbable, it appears generally to remain within moderate limits and not to encroach upon the function to any degree worth mentioning.

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TUBERCULOUS TRACHEOBRONCHITIS

A Study of 500 Consecutive Cases

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THE establishment of routine endoscopic examination of all patients who are under consideration for major surgical collapse therapy procedures for pulmonary tuberculosis, has made it possible, (a) to accumulate a great deal of valuable information regarding tuberculous endobronchitis and tracheitis, (b) to observe the effect of treatment upon this condition and (c) to continue observation of "living pathologic" changes.

Several important facts have been brought to our attention: (1) the progressive nature of the morbid changes that culminate in a strangulating stenosis; (2) the value of treatment in interrupting this chain of events; and (3) the value of individualization of therapeutic methods.

The presence of some degree of inflammatory reaction in the greater number of patients examined has been striking, suggesting that the more severe conditions have their origin in this single inflammatory process. The process thereafter is a gradually progressive one. The area involved becomes more and more extensive and may end in an extensive high degree stenosis or total occlusion of the airway. The fact that every tuberculous patient does not develop such a strangulating stenosis is proof that natural resistance processes interrupt this chain of events in the majority of cases. In addition, careful bronchoscopic management will interrupt many more. Thus, the ultimate number of patients developing a strangulating stenosis or obstruction will be small in terms of the general tuberculosis population.

The rapidity with which the whole series of events transpire varies between individuals, but the orderly progression of the process appears to be generally characteristic. Two apparent exceptions have been noted, although neither has been common in our experience. One is the sudden rupture of an underlying caseating focus into a bronchus. The second is an endobronchitis (or tracheitis) of that portion of the lower respiratory tract that is associated with a demonstrable pulmonary lesion or with generalized miliary tuberculosis. Attention is called to the observations by Ornstein and Epstein in this respect.[13]

From the viewpoint of pathogenesis and treatment, endobronchial tuberculous lesions seem to fall naturally into two large classes, of which one may be further subdivided according to the severity of the lesion. The following classification has been employed and found of real fundamental value clinically and therapeutically:

Group I Extrabronchial

From Pennsylvania State Sanatorium, H. A. Gorman, M.D., Medical Director.
Read (by title) at the Twenty-sixth Annual Meeting of The American Association for Thoracic Surgery, Detroit, Mich., May 29, 30 and 31, 1946.

Group II Intrabronchial
A Type 1 (First, second and third grade)
B Type 2 (First, second and third grade)
C Type 3 (First, second and third grade)
D Type 4 (First, second and third grade)
E Type 5 Miliary

The designations "extrabronchial" and "intrabronchial" have been borrowed from Lloyd and Burdette.[9]

Group I represents bronchial lesions resulting from the rupture of underlying extra bronchial, caseating, tuberculous foci, into the bronchial or tracheal lumen. These foci are generally conceded to be caseating lymph nodes. However, one case which I have observed and which is not included in this series appeared to have arisen from the actual erosion of an underlying parenchymal cavity through the left main-stem bronchial wall. This, however, represents an opinion that has never been conclusively proved.

The life history of these extrabronchial lesions, bronchoscopically, is intensely interesting. They may appear suddenly and at the outset are usually associated with a low Gaffky count positive sputum. The serial sputum examinations on such cases frequently may not be consistently positive unless there is an accompanying open parenchymal tuberculosis. The early phases may be overlooked unless discovered during routine endoscopic examination, or in an otherwise asymptomatic patient. A routine examination may later discover only a localized granulomatous mass, or a completely healed focus which appears as a depressed zone of fibrosis, epithelialized and appearing lighter in color than the surrounding normal bronchial wall. The prognosis in these lesions is generally favorable and they require less energetic treatment than ulcerating lesions of "intrabronchial" origin, provided, of course, that there is either an absence of a parenchymal lesion or that such a lesion, if present, is controllable.

Group II. Intrabronchial lesions.—This category is designated to include tuberculous lesions of the bronchi (or trachea) arising as a "direct" involvement of the mucosa and related structures as contrasted with the "indirect" involvement exemplified by the extrabronchial lesions.

We have included in this category five subgroupings designated as "types." The first four of these types actually represent a series of stages through which a tuberculous mucosal lesion passes, from the very early inflammatory stage to the ultimate possible culmination in a stenosis or an occlusion of the bronchus or trachea. These types may be further subdivided into Grades 1, 2, or 3, and by so doing the extent of the lesion can be comprehended with greater accuracy.

Type 1 has been chosen to include lesions of either the bronchial or tracheal mucosa, ranging from a superficial inflammatory reaction to those showing a superficial erosion, or a superficial ulcerated process not extending into the submucosal structures.

Type 2 includes the ulcerating lesions which extend into the submucosal structures. The ulcerating areas may vary in size, the periulcerating area may

show some redundancy of tissue; granulation overgrowth is not uncommon. In the more advanced phases, a weakening of the bronchial walls may be evident and the lumen may show an abnormal change in shape during the respiratory cycle.

Type 3. The lesions included in this category are considered of a much more serious nature and further more are more difficult to control. The tuberculous process has progressed into the deeper layers with a fixation at times that is out of proportion to the actual area of ulceration. Masses of granulation tissue in the ulcer zone are common and in the later phases (grade three) of these lesions there is actual narrowing, stenosis, or even occlusion of the lumen.

Type 4 comprise those lesions in which healing of the active ulcerating process has occurred but there remains an actual stenosis of the bronchus or trachea. Lesions of this group represent the end result of an ulcerating, stenosing, tuberculous, tracheobronchial process in patients who have survived and have "healed" their active endobronchial lesions.

Type 5. Miliary tuberculous implantations in the mucosa of the bronchi or trachea have been placed in this class. Such an involvement of the mucosa does not imply a generalized miliary tuberculosis. It implies only the presence of isolated miliary tubercles appearing in the immediate surface lining of these respiratory structures. Such cases seem to be rare; the author has seen but two, and suggests the possibility that an intrabronchial, tuberculous, ulcerative process, strictly in the absence of a parenchymal lesion, may have commenced from a miliary implantation of the tubercle bacilli in the mucosa.

The site of active ulceration is most probably the outcome of a combination of two or more factors. There may be a general underlying allergic diathesis as suggested by Oatway and associates[11] a factor that was not thoroughly investigated in this group of cases and cannot be discussed, although it may well be an influencing factor in determining, for many patients, which ones will or will not develop an ulcerating tracheobronchitis. A multiplicity of factors have been described by numbers of other writers.[2, 3, 6, 15]

In the present series, ulcerations have been noted that occurred opposite the orifice of the "draining bronchus," the point of greatest impact of the bacilli-laden Bechic blast from the infected area. Others have appeared to be a continuation of an ulcerating lesion extending from a bronchial orifice, the smaller bronchus itself not being within the field of vision. Still others are prominently located posteriorly, apparently not correlated with the above, but possibly explained by the factor of sputum stagnation. Finally, one case has been noted where the ulcertaions have occurred along the lateral wall of the trachea on the side opposite but a considerable distance away from the draining right upper lobe bronchus, and later the opposite side became ulcerated as the original side showed progressive healing. No dominant single factor can be determined to explain this case, yet following an extrapleural pneumothorax, complete healing of the trachea resulted. This represents the first such instance of an extensively ulcerated trachea (three-fourths of the entire length in addition to the larynx) that, in our experience, has not progressed to a fatal conclusion.

By way of conclusion, it appears that the site of the actual ulceration as it occurs in an already unhealthy mucosa is probably the outcome of a number of diverse factors and not of any one particular influence. These factors are mechanical as well as physiologic. The trauma inflicted upon the mucosa by coughing, in the presence of a tubercle bacilli-infected sputum, produces an inflammatory reaction. At first this reaction is manifested by a dilatation and prominence of the vascular elements. Later, as the intensity of the inflammatory reaction increases, the mucosa becomes reddened, even beefy red, edematous, and boggy, becoming more and more physiologically unhealthy and unable to perform its whole physiologic function. Thus, added trauma directed against a particular area will more readily produce surface damage to the epithelium, opening an avenue of entrance for the tubercle bacillus. It seems of less major importance whether the bacilli enter thereafter and commence active growth as a result of contact with "stagnant sputum," direct implantation, direct extension of a contiguous lesion, or if entrance is first accomplished through involvement of glandular elements. The important fact is the understanding and realization of the dynamics of this process, and then the appropriate therapeutic measures for the control of the tracheobronchial and the parenchymal lesions.

The control of the tracheobronchial lesions is, of course, twofold; directly, through the therapeutic measures directed against the lesion itself, which is endoscopic; and indirectly, through collapse therapy and general physiologic rest. The latter is not within the province of this communication; however, it has been discussed in great detail by many authors.[4, 10, 14, 15, 17] The former can be conducted by endoscopic methods only. Therapeutically, tuberculous lesions of the trachea and bronchus can be discussed from the point of view of the classification just described.

Type 1, comprising lesions of an inflammatory or superficial erosion or ulcerative nature, give the best results with treatment. These cases, in which the process is mildly inflammatory, seldom require prolonged active endoscopic treatment, especially if the parenchymal lesion is promptly controlled. If not, a number will progress to an ulcerative stage, while others remain to show long-standing chronic inflammatory changes of the mucosa, which, it is felt, favor stagnation of secretions, thus predisposing to bronchogenic dissemination of the disease.

The more severe cases will require a longer series of treatments. This treatment in general consists of repeated bronchoscopic aspiration with the evacuation of secretion, cleaning of surfaces and removal of all free material, and the topical application of a silver nitrate solution of varying strengths. In the nonulcerating cases 5 per cent is used, while 10 per cent appears to give the better results in the erosive or ulcerative cases. Silver nitrate is in no way a specific. However, when tolerated and the strength carefully chosen, it reduces the amount of granulation tissue present and in some way is a stimulant to healing.

The improvement noted in this group of patients is generally very rapid, frequently dramatic. Control of the parenchymal lesions is imperative in the advanced cases, for though the "ulcerative" lesions may be controlled, this control cannot be maintained indefinitely if cough and tuberculous sputum are con-

stantly present and permitted to continue to inflict mechanical and physiologic trauma to the mucosa.

The lesions in Type 2 will generally require a more active regime. These lesions show a greater depth of ulceration; varying amounts of redundant tissue or granulation overgrowth may all be present. If they are not, the removal of secretions and the application of 10 per cent (occasionally 15 or 20 per cent) silver nitrate solution to the ulcerating area suffices. If there are granulations present, the area not infrequently becomes coated over with a grayish-white or white material. This "pseudo membrane" is removed with a gauze applicator and the granulating surface, usually bleeding slightly, is "cauterized" with 15 to 30 per cent silver nitrate as the individual case demands. Treatment of this type of lesion must of necessity be more energetic and usually carries over a longer period of time than those of Type 1. Rarely, in cases of this type, have we noted failure of improvement with proper treatment. However, if the period of maximum improvement is overlooked and appropriate collapse procedures are not instituted, the advantage gained will not only be lost, but it might not be possible to regain it with further treatment. It is felt that in these cases an artificial pneumothorax is a definite help, but a thoracoplasty is better postponed until the period of maximum bronchial improvement has been realized, especially in grade three cases.

On the whole, it has been found that the past two types offer by far the best prognosis, and that only a comparative few will progress into the next type if the pulmonary lesion can be effectually controlled.

The next type, Type 3, represents a far more serious endobronchial condition. Not only have the patients of this group shown their inability to combat a tracheobronchial tuberculous infection, but the pulmonary infection itself frequently has progressed beyond control. Treatment is difficult, prolonged, and oftentimes disappointing. Frequent bronchoscopic aspiration helps to reduce the edema and congestion by the removal of stagnant secretions and excess granulation tissue, thus improving natural drainage. Twenty-five to 30 per cent silver nitrate solution is the most generally accepted cautery agent for removing the granulations. Actual cautery must be used in some cases. Collapse therapy in these cases must be handled with the greatest skill. A pneumothorax that will close parenchymal cavities, control tuberculous activity, and eliminate sputum and cough rapidly, is of definite advantage. If this goal cannot be realized, pneumothorax is contraindicated until the lesion is satisfactorily improved and an impending stenosis prevented.[1, 16] If a thoracoplasty is to be instituted, the same criteria are necessary; otherwise, impairment of drainage, as in pneumothorax, will add to the difficulty of the management of these lesions and has, in our experience, rendered the prognosis less favorable.[1, 4, 14, 16 and 19]

The most advanced phases of this type of lesion (Type 3) is manifested by actual stenotic changes. Treatment, although helpful in these patients, is most disappointing. Although some bronchoscopists report that patients are measurably helped by regional collapse therapy (thoracoplasty)[1, 4] coupled with endoscopic treatment, this has not been our experience. A long, protracted case, with eventual fatal outcome has been the rule. These cases have shown

periods of exacerbation and remission, but such remissions have seldom, if ever, become permanent, and the process on the whole has shown an all-over general progression until the disease itself has involved both lungs, and death resulted. A timely pneumonectomy in these cases, when possible, may be life-saving.

Type 4 comprises stenotic lesions in which the active, ulcerative process has healed, but in which the management of the stenosis itself is the principal problem. The more formidable strictures frequently must be dilated until the maximum result is obtained. The intervals between the dilatations are short at first, but they can be lengthened as the individual case permits. Maintenance of the degree of maximum dilatation is essential in order to supply an adequate airway and to permit proper drainage of secretion. Eventual abandonment of treatment in the majority of cases is improbable. It is in this type (that is, absence of active ulceration) that pneumonectomy or lobectomy for tuberculosis is, as yet, best suited.[8, 12, 17]

Type 5. Miliary implantations on the mucosa of the trachea and bronchi have not been observed in sufficient numbers to permit of any definite conclusions. However, the treatment afforded those persons who have been encountered has consisted of periodic bronchoscopic observations with the management of the individual ulcerating lesions depending upon the extent of the ulcerations. (Ulcerations appear to be more punched out in this than in other types). The extent and degree of ulceration is judged according to the four groups just described.

Table I gives in summary form the endoscopic treatment, parenchymal treatment, and prognosis of the five types.

This program of therapy has been followed in the management of the cases shown in Table II. Five-hundred consecutive patients have been studied. This group represents only the tuberculous patients who have been examined routinely during a six-year period (1938 to 1944). This group further represents a total of 1,584 bronchoscopic procedures performed upon these 500 individuals. The age of all patients examined is spread over a wide range, that is, 16 to 53 years. The youngest patient having an active frank ulcerating process was aged 16 (also ages 17, 18, and 19), and the oldest was 44. Other cases were distributed widely between these two extremes.

Table II shows, in concise form, the results of this study with the distribution of cases made according to the types but not the grades that have been described. The group of 316 designated as "normal" include many in whom some inflammatory reaction of the mucosa is present. However, as the majority of all patients examined showed some inflammatory change, all cases that were less extensive than Type 1, grade one, are considered "normal" and, therefore, included in the category. The other categories have not been subdivided according to grade one, two, or three because, in the early period of the study, "grades" were not recognized and to attempt such a distribution now would inject an element of inaccuracy.

The number of cases that have definitely progressed after the institution of therapeutic measures are shown under each type. Of this total of thirteen, three have failed to respond to treatment. Of these three, two are dead and

TABLE I

TYPE	DIRECT TREATMENT	PARENCHYMAL TREATMENT	PROGNOSIS FOR BRONCHIAL "HEALING"
Type 1 Superficial inflammatory reaction to superficial ulceration not extending into submucosal structure	Bronchoscopic aspiration cleaning surface: topical application of $AgNo_3$ 5 per cent (nonulcerative cases) $AgNo_3$ 10 per cent (ulcerative cases)	Collapse therapy (pneumothorax)	Rapid improvement, complete "healing"
Type 2 Ulcerating lesions extending into submucosal structures; may be weakening of bronchial walls	More energetic treatment: removal of secretions: 10, 15, or 20 per cent $AgNo_3$ to ulcerations; granulations removed with gauze applicator followed by 15 to 30 per cent $AgNo_3$	Artificial pneumothorax. Thoracoplasty better postponed	Good prognosis with energetic and somewhat prolonged treatment
Type 3 Deeper layers invaded, with fixation to actual stenosis or occlusion of lumen	Aspirations. Granulations removed by 25 to 30 per cent $AgNo_3$ or actual cautery	Unless artificial pneumothorax or thoracoplasty can rapidly close cavity, control activity and eliminate sputum and cough, both are contraindicated	Guarded in grade 1; poor in stenotic cases
Type 4 Healed ulcerating process but stenosis remains	Dilatation of stricture to supply adequate airway and permit proper drainage of secretion	Pneumonectomy or lobectomy	Stenosis remains; dilatations continued indefinitely
Type 5 Miliary tubercle implantations on bronchus or trachea	Bronchoscopic observation: topical treatment dependent upon condition of tubercle	Insufficient number of cases to determine best form of treatment	Insufficient number of cases to judge prognosis

TABLE II

	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TOTALS	NORMAL	GRAND TOTAL
Initial distribution of cases	*107* 21.4% of grand total	*35* 7.0% of grand total	*35* 7.0% of grand total	*7* 1.4% of grand total	*184* 36.8% of grand total	*316* 63.2% of grand total	500
No. treatments	129	223	486	127	1,270	316	1,584
No. cases showing definite but temporary progression	5 (4.66%)	3 (8.57%)	5 (14.28%)		13		13
No. dead	(0.0%)	2 (5.71%	7 (20.00%)	1 (14.28%)	10		10
No. prognosis grave*		1 (2.85%)	5† (20.00%)	3† (42.86%)	9		9
No. "cured" or prognosis good	102 (95.34%)	32 (91.44%)	23 (60.00%)	3 (42.86%)	160		160

*"Prognosis grave" so considered unless total resection of the lung can be performed successfully.

†Two have already undergone a successful pneumonectomy.

‡One has already undergone a successful pneumonectomy.

the third shows a high grade stenosis of the deep portion of the left main-stem lower bronchus. The ulcerative process has become arrested several times, only to reappear in one to two months. A pneumonectomy is being contemplated at the present time, even though the patient has already undergone a four-stage thoracoplasty and has had a negative sputum for about one year.

Up to the present time, ten patients have died from causes that can be attributed directly to their endobronchial condition. There are nine others still under treatment, whose state at present, as regards the endobronchial condition, is considered grave. Their ultimate death is expected unless the process can be arrested sufficiently to permit a total removal of the lung on the involved side. In one patient, the trachea is so extensively involved that pneumonectomy appears to be an improbability.

All patients in the Type 1 category may be considered "cured" as far as the endobronchial condition is concerned. As already noted, five of the 107 patients did show a progression of the process before it finally became arrested. No case has progressed to an extensive deep ulceration or stenosis, and no patient has died from causes directly attributable to the endobronchitis.

Twenty-three of the Type 3 patients' lesions have been arrested satisfactorily. Forty per cent (twelve) of the total of thirty-five are either dead (7) or considered grave (5). This category, in fact, included the most severe cases and, therefore, it is expected that the duration of treatment is necessarily long and the ultimate mortality rate high and, as a corollary to this, the number ultimately "cured" will be small. In this series, three out of seven were "cured." However, two more could be added, since this table was compiled. Such an addition would then give five "cured" out of nine cases. In any event, this type of lesion is serious from the outset and any success is gratifying.

Any statement that a Type 4 patient is "cured" is misleading, because the stenosis is present and a designation of "cured" indicates that in all probability the airway will remain adequate for an indefinite period of time. I feel, however, that if the stenosis is rigid and of sufficiently high grade to limit the lumen as much as (approximately) 50 per cent, there is a good possibility that total removal of the affected lung (or lobe) will become a necessity sooner or later.

Cases illustrative of Type 5 have not been included because the total number observed is small and full follow-up data are not available. There is no doubt that such a type occurs, but their detection is rare and usually accidental, for such patients are generally asymptomatic.

TABLE III. ANALYSIS OF DEATHS

Uncontrollable tuberculosis	10
Too rapid administration of i.v. fluids postoperatively	2
Empyema	
Not related to bronchial condition	2
Directly related to bronchial condition	10
? Addison's disease	1
Massive pulmonary hemorrhage	2
Renal failure	3
Coronary occlusion	1
Carcinoma of cervix	1
Immediate postoperative deaths	3
"Malignant" tuberculous laryngitis	1
Total	**36**

Of the total 500 patients, there have been thirty-six deaths from all causes. These have been analyzed and are tabulated in Table III. Within the group of thirty-six there is one whose death was immediately caused by a massive pulmonary hemorrhage. In this case the endobronchial process was active and progressing rapidly toward a strangulating stenosis.

COMMENT

Throughout the entire study, one of the most outstanding facts was the presence of some form of mucosal reaction in the greater majority of patients

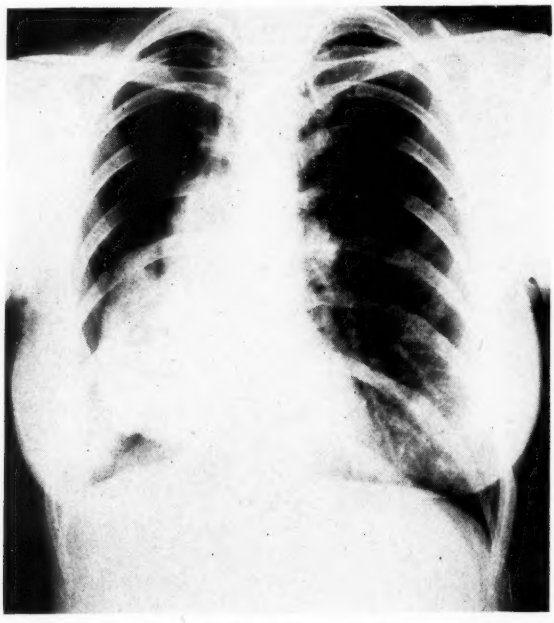

Fig. 1.—K. M. Roentgenogram showing atelectasis of the right lung resulting after the establishment of an artificial pneumothorax in the presence of advanced endobronchial tuberculosis with an accompanying high grade stenosis. This patient is now critically ill and is not expected to survive.

examined, irrespective of age. Because of this it was decided to record no reaction milder than those showing a decided inflammatory change which was characterized not only by blood vessel dilation, but also by a frank reddening of the mucosa, extending beyond the immediate area of the "draining bronchus." On this basis, Table II shows that 184 (36.8 per cent) patients exhibited some change of greater or lesser extent.

The endoscopic treatment included the aspiration of all obtainable secretions, removal of mucoid materials and granulations; in some cases forceps were employed, and, finally, the application of 5, 10, 20 or 30 per cent silver nitrate solution topically. For those unable to tolerate silver nitrate, the actual cautery is recommended and, if this is unavailable, the mechanical removal of granu-

lations is carried out and followed by "soothing" applications, such as gomenol or monochlorphenol. Following this program, Types 1 and 2 yielded most readily and only two patients progressed appreciably after the treatment was instituted. In contrast, seven patients of the Type 3 group of thirty-five failed to respond satisfactorily. Two have had a total pneumonectomy, five others are "grave" and seven are dead.

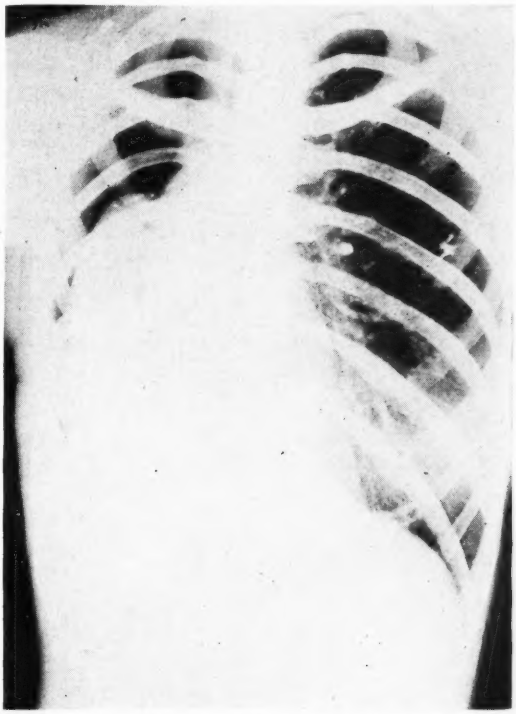

Fig. 2.—Roentgenogram showing atelectasis of the right lung resulting after the establishment of an artificial pneumothorax in the presence of advanced endobronchial tuberculosis with an accompanying high grade stenosis. This patient has died from overwhelming tuberculosis toxemia.

On the whole, the results show, in this as in other conditions, that the earlier the disease is discovered and treated, the better will be the results and the lower will be the mortality and morbidity rates. The only method available to discover this disease is by direct observation through the bronchoscope where the "living pathological changes" can be observed and properly evaluated.

DISCUSSION

The occurrence of an ulcerative process in either the trachea or bronchus always injects a serious problem into the management of any tuberculous patient. Frequently, a contemplated collapse procedure may of necessity have to be postponed. Such a postponement may easily extend beyond the optimum

time or possibly beyond the time when any procedure could be wisely instituted. If stenotic changes are present, a collapse procedure that would otherwise be of real benefit may not only be nullified, but the patient might actually be rendered worse[4, 5, 12 and 19] (Figs. 1 and 2).

Observations made during the study of the present series have demonstrated quite conclusively that endoscopic methods can accomplish a very great deal to relieve and "cure" this type of lesion in many cases. Silver nitrate in percentage ranging from 5 to 30 per cent is easily applied to ulcerating and granulomatous areas. It is, in general, the "cauterizing agent" of choice. However, not every case will tolerate this chemical, as evidenced by the fact that in some patients the application is followed by a marked increase in tissue edema and inflammatory change around the site of application. Therefore, because of the deleterious effects of the silver nitrate, the actual cautery may be cautiously employed and if this is not obtainable, fairly satisfactory results can be obtained by aspiring secretions, removing granulations with the gauze applicator, and applying a "soothing" application such as gomenol or monochlorphenol in mineral oil.

A stenotic lesion once being present, there appear to be only two courses ahead, save for the exceptional case. The one, comprising an indefinite number of bronchoscopic treatments and dilatations, appears to terminate, ultimately, in the loss of the patient. The second is the total removal of the lung or lobe. An occasional case may subside, the stenosing process become "arrested" and after the inflammatory changes have regressed, there will be sufficient relaxation to provide an adequate though limited airway and a pathway for the expulsion of secretions.

It cannot be denied that collapse therapy is a valuable though indirect asset in the management of tracheobronchial tuberculosis. The choice of the procedure, however, must be arrived at with the utmost caution, and this choice must be made with a knowledge of existing endotracheobronchial conditions, knowledge that can be gained only by an endoscopic examination.

The principal symptom and sign, wheezing and atelectasis, develop late in the disease and should not be relied upon. The principal hope of endoscopy in the tuberculous patient is the discovery of pathologic conditions in their early stages and thus, through the judicious and timely application of endoscopic methods, aspiration, cautery, to reduce morbidity and mortality rates.

It is not amiss to suggest that in time all patients with advanced tuberculosis will be bronchoscoped prior to the institution of collapse therapy, just as now we bronchoscope all patients who are candidates for the major surgical collapse procedures.

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SHOULD SOLITARY PULMONARY "METASTASES" BE RESECTED?

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WE WISH to re-emphasize the difficulty which attends the positive diagnosis of a solitary pulmonary metastasis. In some instances a tuberculoma, a cyst, or a primary benign or malignant tumor of the lung may present a roentgenologic appearance indistinguishable from that produced by a solitary metastasis. If the primary tumor under consideration seems to be locally resectable and other inoperable metastases are not present, serious consideration should be given the possibility that the pulmonary lesion may be a separate disease, itself amenable to resection.

Recently, such a problem was encountered. This patient had what appeared to be a malignant bone tumor of the right forearm with a metastasis to the lower lobe of the left lung. He had been given a fatal prognosis and this opinion seemed to be justified by our clinical findings. How incorrect this original interpretation was, is best presented by a detailed report of the case.

CASE REPORT

M. S., a 60-year-old laborer, was first admitted to the University of Chicago Clinics on Nov. 8, 1945. Inquiry revealed that he had been well until January, 1943, when he fell and struck his right wrist. No immediate disability occurred, but shortly afterward he began to notice an aching pain in the injured region. In the course of a month, during which time a swelling of the wrist developed, the pain became progressively more severe so that he avoided the use of his right hand. In February, 1943 roentgenograms revealed a tumor of the distal ulna. In March, 1943, this lesson was curetted and a bone graft placed in the defect. A histologic diagnosis of benign giant cell tumor was made. The wound healed and he was able to work until January, 1944, but by this time there was evidence of recurrence in the form of a swelling extending for about 10 to 12 cm. along the length of the ulna and 5 to 6 cm. about the circumference of the wrist. Roentgenograms revealed further bone destruction and complete resorption of the bone graft. In October, 1944, the lesion was again curetted and on this occasion a diagnosis of giant cell sarcoma was made. Although the wound healed, there was obvious recurrence of the tumor by January, 1945. In February, 1945, he consulted another physician and was advised to have an amputation, but refused operation. In March, 1945, a chest roentgenogram revealed what was interpreted as a metastasis in the base of the left lung. In June, 1945, the skin overlying the forearm tumor broke down and the area of ulceration progressively enlarged. By the time of his admission to the Clinics, the tumor mass had doubled in size. Although he had noted occasional vague chest pains for the previous two years there was no history of cough, hemoptysis, or other chest symptoms.

Physical findings were restricted to the right forearm. On its ulnar surface a fungating mass 8.0 cm. in diameter projected for 6.0 cm. from the normal wrist margin (Fig. 1, *A*). A 3 x 5 cm. ulceration was present on the outer surface of the mass, its floor covered by granulation tissue and a yellowish exudate. The surrounding skin was stretched tightly over the underlying tumor, which extended upward along the forearm for 5.0 cm. from the

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base of the fungus. The lesion was firm and nontender. Although pronation and supination of the forearm were somewhat limited, there was no apparent paralysis or disturbance of sensation in the hand. Blood hemoglobin was 13.4 gm. per cent; red blood count, 4.81 million per cubic millimeter; white blood count, 5,900 per cubic millimeter; Wassermann and Kahn reactions negative.

Roentgenograms of the right forearm (Fig. 1, *B*) revealed an expanding lesion which had almost completely destroyed the distal 9.0 cm. of the ulna, leaving only a peripheral, flaring, osseous shell at the upper margin. Fluoroscopic and roentgenographic examination of the chest showed a well-circumscribed oval density measuring 3.0 cm. in diameter in the base of the left lung posteriorly (Fig. 2, *A* and *B*). This was crossed by a few irregular densities which were interpreted as bronchovascular markings rather than calcified flecks. The impression of the roentgenologist was: (1) sarcoma of the distal end of the right ulna; and (2) solitary metastasis in the left lower lobe of the lung.

A. *B.*

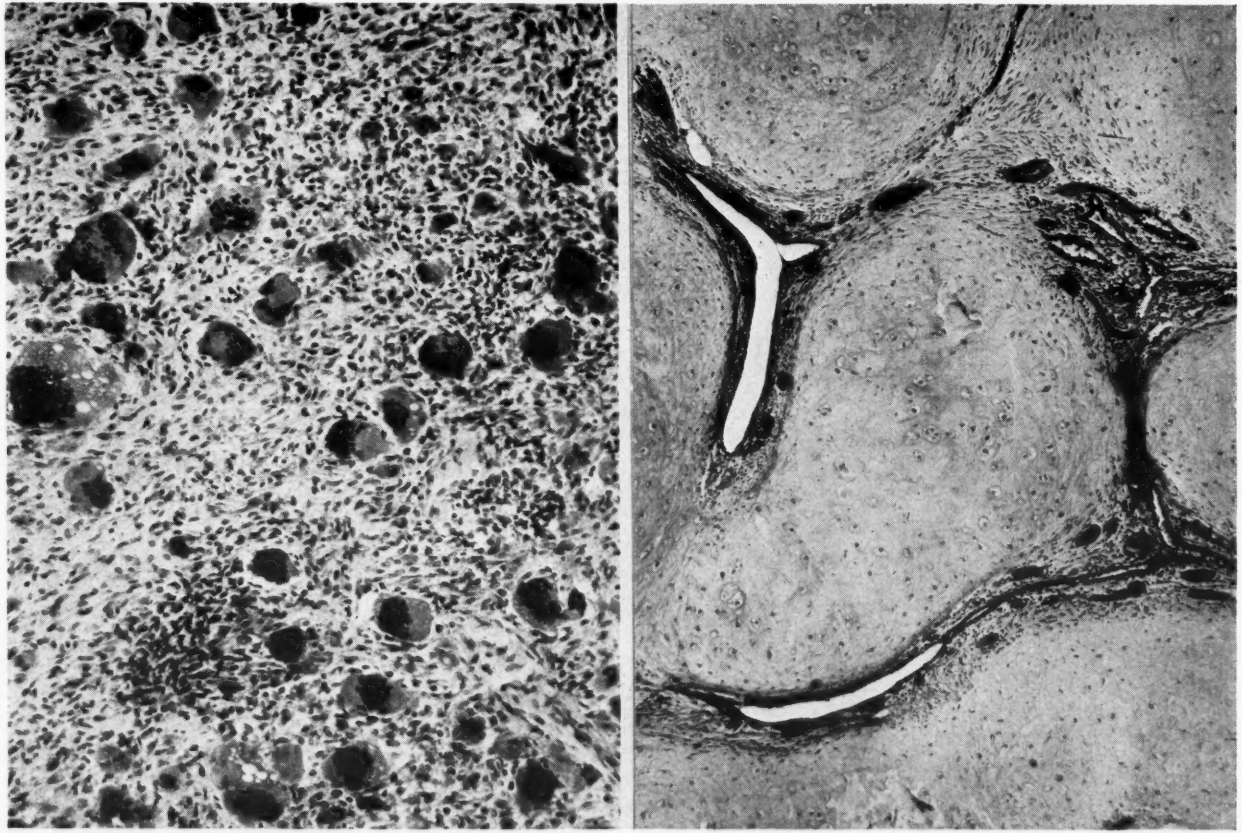
Fig. 1.—*A*, gross appearance of fungating tumor projecting from the ulnar side of the right forearm. *B*, roentgenogram of right wrist showing extensive destruction of the distal ulna by an expansile lesion. A thin, incomplete shell of displaced cortical bone can be seen proximally.

On Oct. 10, 1945, a right supracondylar amputation was performed. Postoperative recovery was uneventful.

Dissection of the specimen revealed that the tumor had replaced the distal portion of the ulna. On both volar and dorsal surfaces the tumor extended to the ulnar side of the radius. The forearm muscles were not grossly involved but were elevated and pushed radially. On longitudinal section the tumor mass presented a thin outer osseous shell surrounding a soft reddish-gray tissue in which large areas of necrosis were seen. Microscopic sections (Fig. 3, *A*) revealed a highly cellular stroma containing many multinucleated giant cells. The nuclei of the stromal cells were moderately pleomorphic and varied from spindle to ovoid in shape. A few hyperchromatic nuclei and occasional mitoses were seen. The giant cells were well defined and contained 20 to 100 nuclei. Near necrotic areas they were

A. *B.*

Fig. 2.—*A* and *B*, anterior and lateral roentgenograms of chest showing well-circumscribed nodular density in posterior periphery of left lower lobe.

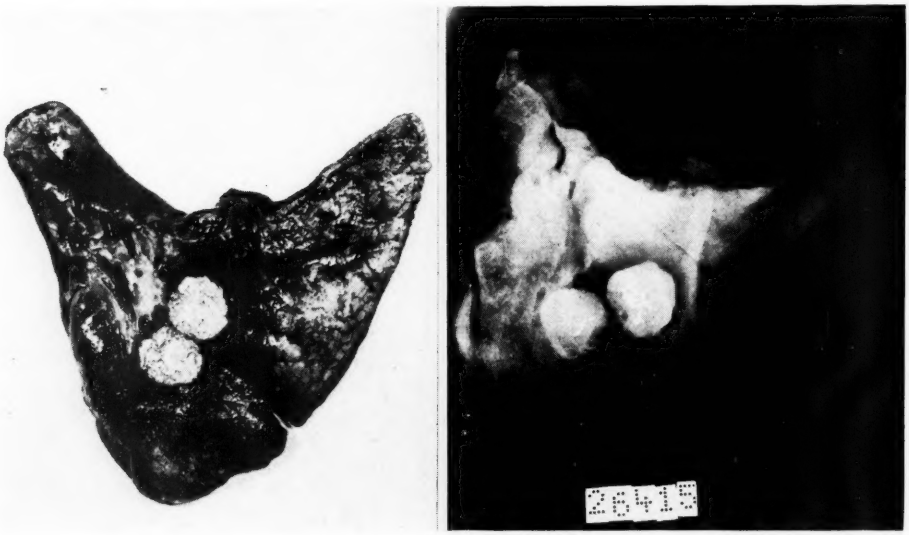


A. *B.*

Fig. 3.—*A*, photomicrograph (×165) of forearm tumor showing numerous multinucleated giant cells embedded in a highly cellular stroma. *B*, photomicrograph (×165) of pulmonary tumor demonstrating lobulated character, predominance of cartilaginous tissue with transition from immature to mature cartilage cells, a small area of calcification, and the interlobular connective tissue, with vessels and cystic structures with epithelial lining.

large and occasionally vacuolated. The giant cell nuclei were generally uniform and only rarely varied in size and shape. A Scharlach R stain revealed only pinpoint collections of fat in the necrotic areas.

Since it is known that both primary benign and malignant tumors and tuberculomas of the lung may produce roentgenologic findings indistinguishable from those demonstrated in this case, and since the nature of this pulmonary density could not be determined with certainty, decision was made to explore the left lung. Bronchoscopic examination revealed a normal bronchial tree. Vital capacity was 5,200 c.c. The patient was digitalized preoperatively and on Nov. 29, 1945, under positive-pressure ethylene, oxygen, and ether anesthesia, the left chest was entered through the bed of the resected seventh rib. A single solid mass was found in the posterior periphery of the lower lobe. The rest of the left lung and both parietal and visceral pleurae were free of any abnormality. The phrenic nerve was crushed and a left lower lobectomy was performed. Whole blood, 1,200 c.c., was given during and immediately after the operation. An uneventful postoperative recovery was facilitated by the use of nasal oxygen, continuous chest suction, and penicillin. Fluoroscopic examination on Dec. 5, 1945, showed the lungs to be clear and well expanded. The patient was discharged from the hospital on Dec. 11, 1945, and has since remained in good health.



A. *B.*

Fig. 4.—*A*, photograph of cut left lower lobe showing well-circumscribed tumor mass with gross evidence of lobulation. *B*, roentgenogram of specimen demonstrating partial calcification of the pulmonary tumor.

On section of the resected lobe a hard egg-shaped mass measuring 2.5 × 2.5 × 3.0 cm. was encountered posteriorly (Fig. 4, *A*). The mass was discrete and shelled easily from the adjacent lung tissue which was entirely normal. There was no invasion of or impingement on the bronchial structure of the lobe though one of the small bronchial divisions disappeared in the region of the tumor. The surface of the nodule resembled cartilage and grossly appeared to be partially calcified. The tumor was nodular throughout, its substance being divided by fissures which contained small blood vessels. These vessels formed a network and were particularly prominent in the periphery of the mass. A roentgenogram of the specimen (Fig. 4, *B*) demonstrated irregular flecks of calcium within the tumor. The

lobulation noted grossly became a prominent feature on microscopic examination. Each lobule was composed of a peripheral zone of spindle cells resembling fibroblasts which gradually became less numerous towards the center and blended with the cartilage cells which formed the major portion of the tumor (Fig. 3, *B*). This architectural pattern suggested a growth transition from primitive to mature cartilage cells. Calcification was observed in the central portions of several of the lobules. No multinucleated giant cells were seen. Throughout the tumor the interlobular substance consisted of a loosely arranged, fibrous connective tissue containing numerous small vessels and cystic structures lined with a low, nonciliated, cuboidal epithelium.

COMMENT

The number of hamartomas of the lung now recorded nears 100 and reports of giant cell tumors of bone are numerous. Jaffe, Lichtenstein, and Portis,[1] have recently reviewed the characteristics of giant cell tumors and their so-called variants. In the reports of Hickey and Simpson,[2] Verga,[3] Benninghoven and Peirce,[4] Edling,[5] and McDonald, Harrington, and Clagett,[6] the characteristics of the pulmonary hamartomas are well stated. Single case reports of such tumors would be of little value, but their simultaneous occurrence posed an unusual clinical problem in that the pulmonary tumor simulated a metastasis from the "primary" bone lesion. Various authors have emphasized the advisability of exploratory thoracotomy when doubt exists as to the exact nature of a pulmonary lesion. In this case two roentgenologists had thought without reservation that the pulmonary density represented a metastasis from the tumor of the forearm. Histologic examination, however, revealed the presence of islands of cartilage lying in a connective tissue stroma interspersed with vessels and cystic structures lined by cuboidal epithelium, all the characteristics of a pulmonary hamartoma. Although there was some evidence of pleomorphism among the stromal cells of the giant cell tumor and occasional mitoses were noted, these were not thought to be sufficient to make a definite diagnosis of malignancy.

Thus this patient whose clinical picture at first seemed to warrant grave prognosis was found to have a giant cell tumor of questionable malignancy and an entirely unrelated benign pulmonary tumor.

SUMMARY

1. A case of coincident giant cell tumor of the right ulna and a hamartoma of the left lung which simulated a metastasis is reported.

2. The value of exploratory thoracotomy is re-emphasized.

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A STUDY OF VARIATIONS OF THE BRONCHOPULMONARY SEGMENTS IN THE LEFT UPPER LOBE

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IN A recent study of the bronchopulmonary segments of the left upper lobe, Boyden and Hartmann[4] have presented an analysis of the variations of bronchial, arterial, and venous patterns based on the dissection of fifty specimens. They have suggested that to complete the study a series of combined injections and dissections would be desirable in order to correlate variations of hilar configurations with surface projections.

In 1943, Jackson and Huber[9] cautioned that it is a mistake to hold too rigid a concept of the bronchopulmonary segment, and the recent studies of Brock[6] have amply supported this warning. The latter has included in his papers a series of well-executed drawings of the various lobes with the individual segmental bronchi differentially injected with colored gelatin solutions. Variations of extent and position of the segments within the lobe, and of the segmental composition of certain important areas, are clearly demonstrated. The various segments are identified according to the author's evaluation of the bronchial pattern. However, it has seemed desirable to modify this procedure so as to present a simultaneous record of surface projections and the related bronchial tree. In this way, variations of the bronchial pattern can be more clearly demonstrated and more fully debated.

MATERIAL AND METHODS

Thirteen left upper lobes were obtained from individuals who had no history of significant respiratory disease and in whom the left upper lobes were "normal" in gross appearance, showing, at most, a mild degree of emphysema (Fig. 5) or minimal old tuberculous scarring (Fig. 2). The fresh specimens were usually kept in a refrigerator for twenty-four to forty-eight hours. Before injection, air contained in the lobe was manually expressed so far as possible, and a preliminary dissection of the hilum was done, so that a fair appraisal of the bronchial pattern could be made. In general, the dissection was limited to a zone within a radius of 3 cm. of the stem bronchus, for it was found that more extensive dissection led to almost unavoidable damage to the bronchial wall. Then, with the lung submerged in warm water, deeply colored gelatin solutions at approximately 90° F. were introduced seriatim into the individual segmental and subsegmental bronchi. Various colors were used to distinguish the segments. The injection was made with a 100 c.c. glass syringe through a number 15 cannula prepared in the University shops by fashioning a grooved metal shoulder on the tip of a 15 B-D intravenous needle from which the point

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had been removed. Only moderate pressure was exerted in order not to rupture the alveolar walls and cause subpleural extravasation of the injected mass. The amount introduced into each bronchus was proportionate to its size and the apparent completeness of the filling in the segment which it served. After injection, the bronchus was ligated. Without doubt, discrepancies in the degree of filling occurred, but if of significant magnitude, they were quickly recognized and noted in the record (see Fig. 1).

The gelatin solutions were prepared by adding 70 to 75 Gm. of U.S.P. gelatin powder to 500 c.c. boiling tap water in which 10 Gm. of potassium iodide had been dissolved. The latter reagent was used to lower the temperature at which the mass would jell. Two per cent solutions of aniline dyes, such as are commercially available, were used.

After the entire lobe had been injected in contrasting colors, the specimen was placed in 10 per cent formalin for twelve to forty-eight hours. At the end of this time, the gelatin was firmly set to an almost rubbery consistency and was very easy to handle. Before fixation, however, it was usually found advisable to trace the limits of the segmental areas in India ink, as the formalin, by rendering the pleura somewhat opaque, frequently obscured certain of the boundaries. After removal from the formalin, a more detailed dissection of the hilum was carried out, and accurate camera lucida sketches made of the bronchial tree in situ and of the costal surface.

For the record, three views were selected: (1) the costal surface; (2) the mediastinal aspect, corresponding to the lateral bronchogram; and (3) an anterior elevation of the bronchial tree, corresponding to the "surgical" view of the hilum when an anterior or lateral approach is used and the left upper lobe retracted downward.

THE PREVAILING BRONCHIAL PATTERN

In interpretation of the specimens, the nomenclature suggested by Jackson and Huber (1943) has been used, and, in addition, the system of enumeration suggested by Boyden.[2, 4] The latter system has been found very useful in dealing with large numbers of bronchial patterns. The various segments are designated in terms of their position within the lobe, the terms anterior, lateral, and posterior being preferred to pectoral, axillary, and subapical (Brock[6]).

In brief, the usual disposition of the bronchi within the left upper lobe has been shown by Brock, Foster-Carter,[8] Appleton,[1] Boyden, and others to be similar to the pattern displayed in Fig. 1.* The left upper lobe bronchus bifurcates into a superior and an inferior (or lingular) division. The upper division then divides into an anterior (B^2) and an apical-posterior segmental bronchus (B^{1+3}). Of these, the former (B^2), usually divides into a posterior ramus (B^2a) which reaches the interlobar fissure and adjacent costal surface, and an anterior ramus (B^2b), which supplies the more anterior costal and mediastinal surfaces.† The apical-posterior bronchus (B^{1+3}) is described as subdividing into

*Except that Foster-Carter describes an anterior and lateral segment in the lingular zone, Appleton a superior, inferior, and axillary segment arising from the lingular bronchus, and Jackson and Huber an anterior segment that fails to reach the costal margin of the interlobar fissure.

†Either B^2a or B^2b, or the main stem of B^2, may give rise to an exclusively costal branch (the "B^2 lateral" of Figs. 1, 2, 3, and 5). This segment, therefore, may consist of anterior, lateral, and posterior subdivisions.[4]

an apical subsegmental bronchus (B^1) and a posterior subsegmental bronchus (B^3). The former may be further subdivided into apical (B^1a) and anterior (B^1b) rami, the latter into apical (B^3a) and posterior (B^3b) rami. However, the mode of branching of the apical-posterior bronchus (B^{1+3}) is subject to considerable variation.

The lingular division has two components, a superior segmental bronchus (B^4), and an inferior (B^5), which often exhibits a fourth or phrenic surface. On occasion, however, an anterior-posterior orientation may be apparent (Fig. 3), which resembles the arrangement in the middle lobe. This has, until lately, represented the "classic" orientation of the lingular segments, although the accumulated experience of recent investigators indicates that this arrangement should be considered atypical and that the superior-inferior pattern is the prevailing one.

Brock has fully described the segmental representation on the surface of the main portion of the left upper lobe. The anterior segment (B^2) is clearly the dominant one, running as a broad band across the lobe, wider at the anterior margin than at the interlobar fissure, where, not infrequently, it fails to find surface representation (compare Figs. 1 and 3). In all thirteen of the specimens studied, the B^2 surface area was equal to or (usually) greater than B^1 and B^3 combined.

Certain surface landmarks seem to be of importance with regard to the segments. As Churchill and Belsey[7] have pointed out, there is commonly an indentation or notch on the anterior margin of the upper lobe marking the limit of the lingular segment (Figs. 1, 3, and 4). Although he agrees that this is a landmark of considerable usefulness, Brock has remarked that it may not be the only indentation on the anterior margin (Fig. 5) nor does it always prove to be a reliable guide (Fig. 6).

On the mediastinal aspect, there are three prominent linear elevations, of which the most conspicuous is the ridge formed by the junction of the mediastinal and interlobar surfaces. This extends from the hilum to the lingula (*C.l*, Fig. 1) and has been named the "frenum" of the left upper lobe by Churchill and Belsey (1939). The presence of a correspondingly placed "frenum" on the middle lobe of the lung, has also been noted by Boyden and Hemre (unpublished data).

The other two elevations on the mediastinal surface are more in the nature of low ridges or prominent raised lines. After considerable discussion with Dr. Boyden these have been named the *crista subclavia* (*C.s.*) and *crista posterior* (*C.p.*, Fig. 1).* The first of these usually lies in the territory of B^1, and is a well-marked ridge forming the superior and posterior margin of the subclavian groove. The second usually lies within the confines of the posterior segment (*C.p.*, Fig. 1) and is formed by the junction of the interlobar and the curved posterior costal surfaces, that is, it marks the upper limit of the interlobar surface of the superior lobe.

*Originally, in the interests of uniformity, we had considered naming the frenum "crista lingularis," but the frenum is such a distinctive anatomic structure that we felt that Churchill's apt designation should be retained.

VARIATIONS IN THE PREVAILING PATTERN

1. *The Occurrence of an Accessory Anterior Bronchus, BX^2b.*—Boyden and Hartmann have demonstrated that the principal disturbance in the left upper lobe centers about the development of an accessory anterior bronchus (BX^2b), which is usually accompanied by a downward displacement of the anterior segmental bronchus (B^2) so that a pattern approaching a trifurcation of the left upper lobe bronchus is presented. This variant should be demonstrable on a satisfactory bronchogram. The specimens shown in Figs. 4 and 5 have been selected to demonstrate this variation.

The first of these (Fig. 4) is characterized not only by a trifurcate branching of the lobar bronchus, but also by relatively small lingular segments. (Reduction in size of the latter is not a constant feature of this anomaly.) The specimen is interpreted as follows. The apical bronchus lacks its usual anterior ramus (B^1b), a not uncommon variation, as reference to the other figures will show. The anterior segmental bronchus, B^2, is displaced downward and forms the central limb of the trifurcation (see central sketch of Fig. 4; in the right hand sketch, the origin of B^2a and B^2b from the middle orifice is obscured by the obliquity of the view). This bronchus is complete with respect to its posterior and anterior rami, and supplies a surface area lower than its usual territory, a fact further emphasized by the relatively small lingular segments. Between the anterior segmental bronchus, just described, and the apical segment, there is a "segmental" bronchus supplying a large anterior portion of the lobe (area in white) and extending almost into the apex. This has been designated BX^2b, the "X" implying that it is an accessory outgrowth which has taken over much of the territory usually supplied by another bronchus, in this case B^2b. To complete the bronchial tree, it may be noted that the lingular division is incomplete with respect to its superior segment; in fact, B^4a (posterior ramus) is absent, and B^4b (anterior ramus) is relatively small and does not find its usual representation on the costal surface.

Considering this specimen by itself, one might argue that the central limb of the trifurcation represents not an anterior segmental bronchus (B^2) but a superior lingular segmental bronchus (B^4) which has been "displaced" upward. Granted that appearances may seem to favor a view that does not require an "accessory" bronchus, we may adduce the following evidence in support of the first interpretation: (1) the bronchus in question supplies an area which is not primarily in the lingular area but rather in the main body of the left upper lobe; (2) analysis of the fifty specimens, previously cited, showed that where a trifurcate pattern was found (Plate 1, Boyden and Hartmann) the lingular division was complete with respect to its superior and inferior components (stated differently, the lingular division, as the terminal trunk of the lobe, was found to be relatively stable, in which respect it may be compared to the terminal bronchus of the right upper lobe, B^2 (Boyden and Scannell[5]); (3) a small branch of the inferior division, albeit a rudimentary one, can be demonstrated as at least part of a superior segment (in this case B^4b); (4) if the trifurcation is viewed bronchoscopically, the keel between the lingular

EXPLANATION OF THE PLATES

(Sketches rendered for publication by Lawrence B. Benson)

Each specimen is represented by a view of the costal surface and the medial surface of the lobe, and a mediastinal view of the bronchial tree. The bronchi are enumerated according to the following plan:

B^1, apical segmental bronchus
- B^1a, apical ramus
- B^1b, anterior ramus

B^2, anterior segmental bronchus
- B^2a, posterior ramus
- B^2, lateral, from either B^2, B^2a or B^2b
- B^2b, anterior ramus

B^3, posterior segmental bronchus
- B^3a, apical ramus
- B^3b, posterior ramus

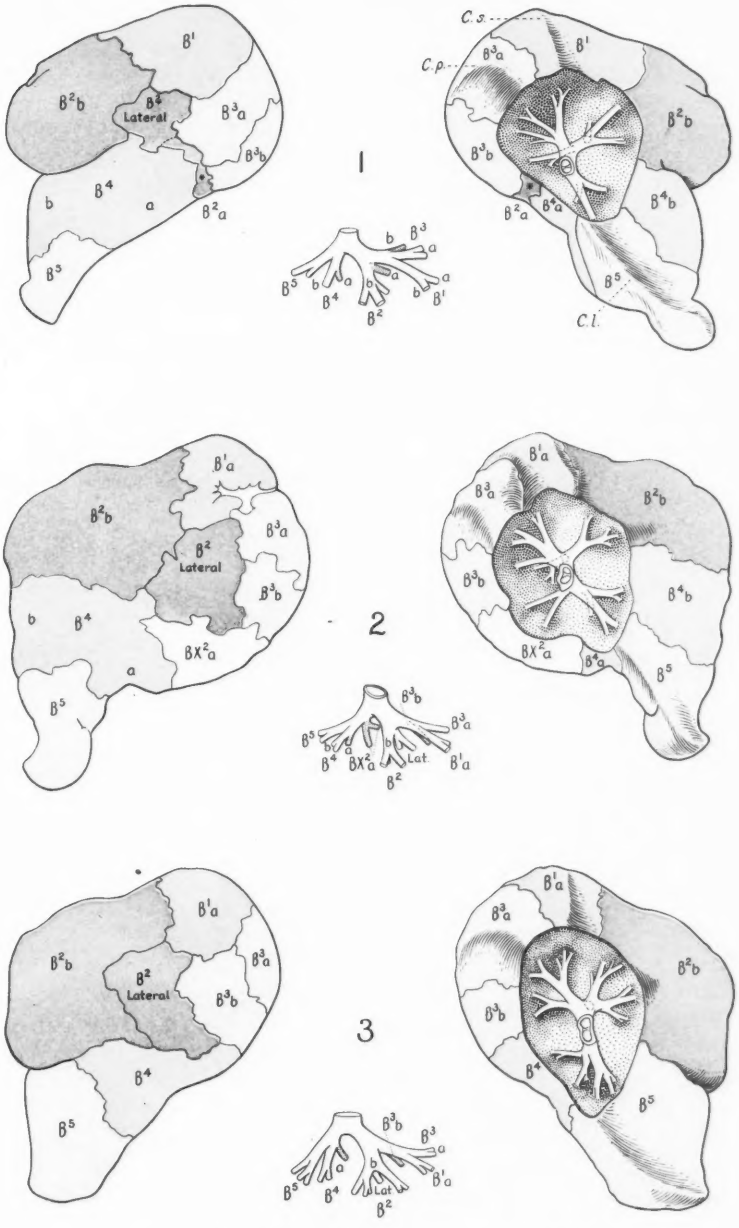
B^4, superior lingular segmental bronchus
- B^4a, posterior ramus
- B^4b, anterior ramus

B^5, inferior lingular bronchus

Fig. 1.—Injected specimen (No. 1) demonstrating the prevailing pattern in the series described by Boyden and Hartmann. Costal surface on left, mediastinal view of bronchial tree in center, medial surface on right. *B^2a* failed to fill with the injection mass and is indicated by an asterisk. *C.l.*, frenum (or lingular crest), *C.p.*, posterior crest, *C.s.*, subclavian crest.

Fig. 2.—Injected specimen (No. 3) illustrating the occurrence of an accessory bronchus, *BX^2a*, to supply the territory usually served by *B^2a*, which is absent in this instance. The irregular area, depicted on the costal surface, between *B^1* and *B^3*, represents an old tuberculous scar.

Fig. 3.—Injected specimen (No. 5) demonstrating the absence of *B^2a* and compensatory expansion of the superior lingular segment (*B^4*). In addition, its anterior ramus (*B^4b*) is absent, so that there is an atypical arrangement of the lingular segments.



Figs. 1, 2, and 3.—*(For legends, see opposite page.)*

division and B^2 is higher than that between B^2 and the rest of the superior division, thereby allying the bronchus in question with the superior division.

In the specimen shown in Fig. 5, the upper lobe bronchus bifurcates and the lingular division has its full complement of segments. However, a new, sizeable stem (BX^2b?) has appeared between the anterior and apical bronchi. The interrogation mark has been used to indicate that this specimen probably represents a transitional stage in the formation of the accessory bronchus (cf. Fig. e, plate 1, Boyden and Hartmann). The anterior bronchus (B^2), is not appreciably displaced downward; however, the bronchus in question is as large as either B^2 or B^{1+3} and forms a virtual trifurcation with them so that it may be regarded as an accessory bronchus. Its surface projection is almost entirely anterior and it has no posterior ramus. For that matter, neither does B^2, although the latter has a well-defined "lateral" ramus. The fact that there is little dislocation of the anterior bronchus (B^2), and that the accessory bronchus is found so far out from the hilum makes this specimen of greater theoretical than clinical significance.

In the specimen shown in Fig. 6, an interesting situation has arisen. There is a trifurcate pattern, the lingular division is complete, and the central limb of the trifurcation supplies the area along the interlobar fissure which is usually served by the posterior ramus of the anterior segmental bronchus (B^2a). However, the anterior ramus (B^2b) has not been displaced inferiorly and does not arise in conjunction with B^2a. (If it had so arisen its expected position would be that which is indicated by dotted lines in the mediastinal view.) In other words, there has been a separation of the two components of B^2. This is the only instance of this anomaly which has been observed in this laboratory in sixty-three carefully recorded specimens of the left upper lobe. Also, such an arrangement as this, with B^2a arising as an independent branch of the upper lobe bronchus, is distinctly unusual in the experience of Brock. It would appear to represent what has formerly been described by several authors as the lateral or axillary segmental bronchus of the left upper lobe.

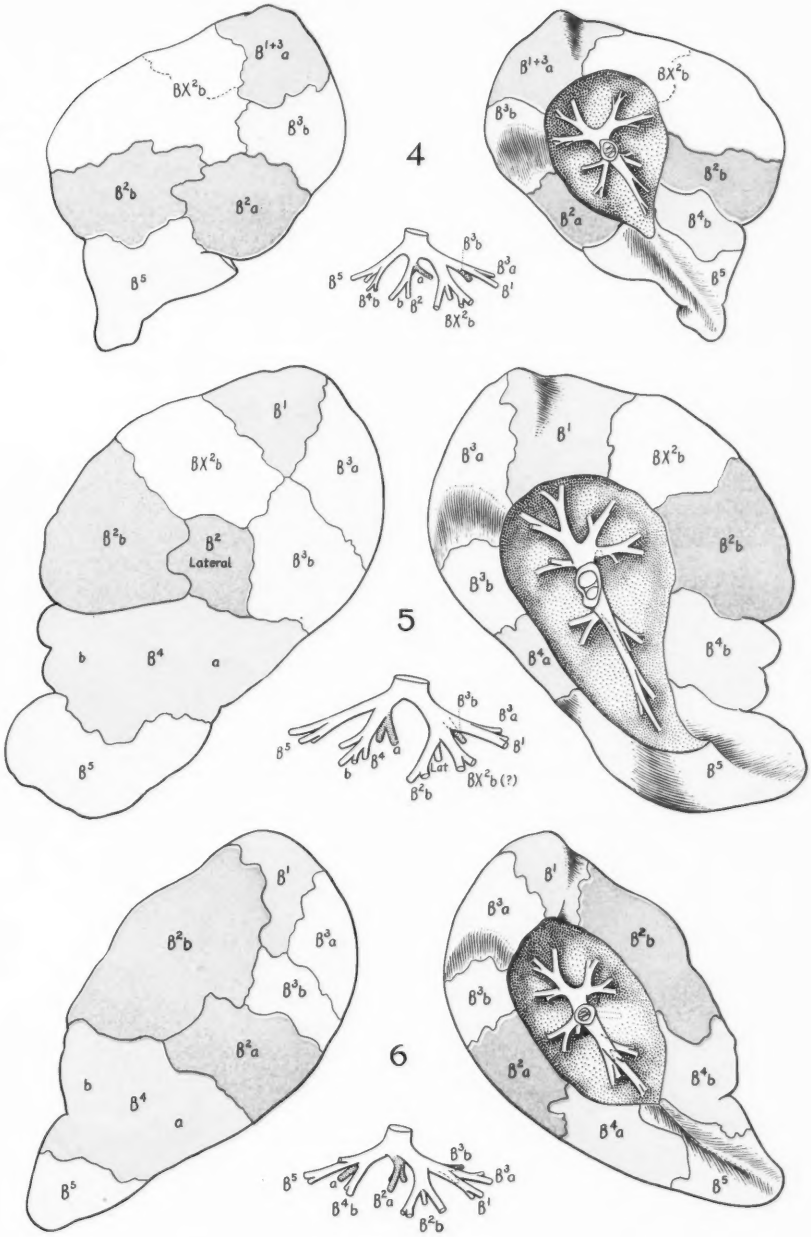
2. *Variations (in Representation) Along the Interlobar Fissure.*—Brock has very clearly demonstrated the variations in the composition of the "axillary" area of the left upper lobe (Brock's Figs. 51, 52, 53, and 54). These are usually centered about the posterior ramus of the anterior segmental bronchus (B^2a). Boyden and Hartmann found that in 40 per cent of their specimens B^2a was absent, that is, no ramus of the anterior bronchus reached the interlobar fissure. In such instances it was apparent that the defect was remedied by compensatory expansion of the adjacent subsegments (B^3b and B^4a), or, less commonly, by the appearance of an accessory branch (BX^2a). Fig. 2 demonstrates the latter arrangement where the accessory ramus (BX^2a) arises from the lingular division.* Boyden has pointed out that this constitutes one of the anatomic hazards of lingulectomy.[3] In the majority of instances of an absent B^2a, a situation similar to that depicted in Figs. 3 and 5 occurs, where the area under discussion is served by branches of the posterior segment (B^3b) and su-

*In Fig. 6 one might argue that the central limb of the trifurcation represents a BX^2a rather than an unqualified B^2a. However, in none other of sixty-three specimens of which we have records has a BX^2a participated in a trifurcation, while the B^2 bronchus, as a whole, took part in a trifurcation in some fourteen instances, exclusive of the present one.

Fig. 4.—Injected specimen (No. 18), depicting a trifurcate branching of the upper lobe bronchus caused by downward displacement of the anterior segmental bronchus, B^2, which then forms the central limb of the trifurcation; an accessory bronchus, BX^2b, has appeared to take over the area "vacated" by B^2b. The superior lingular bronchus, B^4, is incomplete, since its posterior ramus is absent and it lacks representation on the costal surface. B^1 and B^3a were not injected separately in this specimen.

Fig. 5.—Injected specimen (No. 16), representing a transitional stage in the formation of an accessory anterior bronchus, here labeled $BX^2b(?)$. The anterior segmental bronchus has not been displaced downward. B^3a is distributed to the posterior part of the apex.

Fig. 6.—Injected specimen (No. 11) demonstrating a trifurcate pattern with B^2a forming the central limb of the trifurcation. The anterior ramus, B^2b, has not been displaced downward along with B^2a (to the position indicated by the dotted lines as in Fig. 4). This specimen, therefore, illustrates a separation of the two components of B^2.



Figs. 4, 5, and 6.—*(For legends, see opposite page.)*

perior lingular segment (B^4a). Attempts to find "X" branches among these, as might be done in the B^4a branch of Fig. 3, would probably introduce unnecessary distinctions. However, participation of the superior lingular segment in the "axillary" area is of considerable clinical importance (Brock).

3. *Variations in Bronchial Supply to the Apex.*—In this series of thirteen specimens only one (not illustrated in the plates) showed a posterior segment (B^3) extending upward to include the highest point of the lung. This is in accord with Brock's findings. However, if the apex be considered as that portion of the lung which lies above the plane of the first rib, and there appears to be no unanimity in defining this area, then in four of the thirteen specimens the posterior segment appeared to enter into the apex. However, it must be admitted that it is frequently most difficult to define the limits of the apex in the ablated lung. In the series of fifty dissections of Boyden and Hartmann, it appeared that in 90 per cent of the specimens, B^3 was distributed to the posterior part of the apex.

In the present series of thirteen, an interesting situation has been found relative to the mode of origin of the posterior ramus (B^3b) of the posterior segment. In twelve of the thirteen, B^3b arose independently from the apical-posterior stem, to supply a region below the posterior ridge, while the superior ramus (B^3a) arose further along to form a bifurcation with the apical bronchus (B^1). This is in marked contrast to the situation found in the right upper lobe,[5] where the posterior (B^3) and apical (B^1) bronchi are generally distinct.

SUMMARY

A relatively simple but informative method of studying the bronchopulmonary segments by combined injection and dissection has been described. The prevailing pattern of segments in the left upper lobe has been reviewed. The three major variations in the left upper lobe have been discussed and representative specimens selected for their demonstration. These variations are: (1) the occurrence of an accessory anterior bronchus (BX^2b) associated with downward displacement of B^2; (2) variations in distribution of the bronchi in the axillary area and along the interlobar fissures, and (3) variations in composition of the apex.

The author wishes to express his gratitude to Professor E. A. Boyden for his advice and many helpful suggestions during the course of the study and to Dr. J. F. Hartmann for his helpful criticism of the text.

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EXPERIENCE WITH THORACIC AND THORACOABDOMINAL WOUNDS IN AN EVACUATION HOSPITAL

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THIS presentation is based upon a study of 285 battle casualties with penetrating or perforating wounds of the thorax treated in a 750-bed evacuation hospital during the Italian campaign from the day of invasion, Sept. 9, 1943, until the hospital was inactivated Sept. 30, 1945. It concerns itself with the management of penetrating and perforating wounds of the thorax, and thoracoabdominal wounds caused by a single missile. All wounds entered into or traversed the pleural cavity. Thoracic wounds not involving the pleural cavity are excluded from this report.

Unlike wounds of the abdomen or the cranium, a wound which penetrates or perforates the thorax does not always demand exploration. When confronted by a wound of the thorax, the question that presents itself in regard to management is whether the patient will require a thoracotomy, or whether debridement of the soft-tissue wound and treatment of the pleural space will suffice. Clinical necessity, therefore, forces one to classify such cases into one of two categories, namely, (1) wounds that require thoracotomy and (2) wounds that do not require thoracotomy. The greater number of cases fell into the latter group, which required only debridement of the wound of the thoracic wall and proper care of the pleural cavity. Wounds of the chest requiring exploratory thoracotomy occurred with less frequency. Thus, of a total of 285 patients with thoracic wounds, sixty-five, or 22.8 per cent presented indications for thoracotomy. These sixty-five patients include those in which there were thoracoabdominal or suspected thoracoabdominal wounds. All of the latter, forty-four in number, were approached through the thorax because of the relative ease of exposure of the peritoneal contents through the diaphragm.

There were, therefore, 241 cases in which it was apparent that the wound was limited to the pleural cavity and its contents. Of these, only twenty-one, or 8.7 per cent, presented indications for thoracotomy.

I. WOUNDS THAT REQUIRE THORACOTOMY

The battle casualty received his introduction to surgical treatment at hospitals in the combat zone, usually in the mobile Evacuation or Field Hospitals where specialized surgical teams were assigned. Initial surgery at these installations concerned itself with procedures directed toward the re-establishment of physiological equilibrium, and toward the prevention of infection. The restoration of cardiorespiratory equilibrium in patients with thoracic injuries was accomplished in most instances by closure of the thoracic wound, and by emptying the pleural cavity of air and blood. The prevention of infection was usually

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achieved by debridement of soiled and devitalized tissue and the early obliteration of the pleural space by immediate expansion of the lung. However, there remained a group of cases (22.8 per cent of this series) where the nature of the injury demanded, in addition, an exploration.

Experience with thoracic wounds crystallized the following five indications for exploratory thoracotomy, and they are listed in the order of frequency with which they occurred: (1) the anatomic likelihood of diaphragmatic penetration; (2) the presence of large intrapulmonary and intrapleural foreign bodies; (3) the presence of missiles in, or traversing, the mediastinum; (4) wounds of the large bronchi; and (5) continuing intrapleural hemorrhage.

(1) *Diaphragmatic Penetration.*—Wounds which penetrated the diaphragm were the most common indication for exploration of the thoracic cavity. Of sixty-five thoracotomies performed for penetrating or perforating wounds of the chest, forty-four, or 67.7 per cent, were done because of known injury to the diaphragm, or because the presence of such a wound could not be excluded without exploration.

With wounds of the right diaphragm, primary concern is directed toward associated injury of the liver and the prevention of bile seepage into the pleural and the peritoneal cavities. With wounds of the left diaphragm, one's concern is with associated lesions of the spleen and the neighboring hollow viscera. Trauma of the stomach, the spleen, and the splenic flexure of the colon is common when the left diaphragm is penetrated, because of the location of these organs high in the left upper quadrant of the abdomen. The kidneys may be traumatized by penetration of either diaphragm. The number of times each organ was involved is as follows: liver, 21; spleen, 6; stomach, 5; colon, 3; kidney, 2.

Roentgen examination of the chest and upper abdomen in the posteroanterior and the lateral positions was indispensable in determining whether the missile had perforated the diaphragm. An effort was always made to secure the posteroanterior film with the patient in an upright position, in order that the degree of lung collapse and the fluid level of the hemopneumothorax as well as the position of the missile could be visualized. It was found that routine roentgen films of the chest and the upper abdomen taken in the lateral position were inadequate to visualize the presence of a metallic fragment in this region, because of the heavy shadow cast by the liver. Hence, films of this view were taken with the patient in the prone position in order that a Potter-Bucky grid could be employed.

The position of the missile having then been determined, its course through the body from the point of entrance to the point of lodgment was mentally visualized and the anatomic structures it had traversed were conjectured. In perforating wounds, where the missile had passed through the body, the pathway of the missile was imagined by noting the point of entrance and exit. During operative procedures, particular attention was paid to whether or not the course of a missile was deflected as a result of striking bony structures. In no case was the pathway ever observed to deviate from a straight line through the body. The alleged propensity of a bullet being able to circumnavigate the thoracic wall by "skidding" along the periosteum of a rib was never encountered.

Although the necessity for adequate radiologic examination is stressed, it was found to be of little importance without a complete inspection of the patient's wounds and a close study of the relationship between the physical and the radiographic findings. With certain cases, however, in spite of close appraisal of the patient and study of the films, it was often impossible to know for certain whether or not the missile had penetrated the diaphragm, and exploration of the thorax had to be undertaken.

Wounds of the right diaphragm: In the early part of the campaign, the high incidence of postoperative subphrenic abscess and right bile pleuritis with empyema soon made it apparent that simply to suture the rent made by a missile in the right diaphragm was insufficient. It was necessary to establish a method whereby decompression of the subphrenic space of bile and accumulated necrotic liver tissue could be accomplished. The practice of incising the diaphragm to insert abdominal drains which were brought out through a subcostal stab wound proved satisfactory (Fig. 1). When packing was used to control bleeding from the liver wound, its free end was also drawn out through the same incision. Closure of the diaphragm was made with interrupted silk sutures, exercising care to include the serous lining of its peritoneal and pleural surfaces.

Missiles which penetrate the chest and pierce the dome of the diaphragm enter the liver in its "bare area." While the necrotic substances resulting from inadequately drained wounds of the intraperitoneal portions of the liver are absorbed by the peritoneum and the omentum, a wound within the "bare area" has no outlet into the peritoneal cavity. Its by-products collect within the confined space bounded peripherally by the coronary hepatic ligament, above by the undersurface of the diaphragm, and below by the bare liver surface. Accumulating bile, therefore, soon finds its way into the pleural cavity by way of the diaphragmatic perforation inflicted by the missile, in spite of closure of this wound. To insure surgical drainage, it is necessary to gain access to the enclosed space. This was accomplished by severing the coronary ligament from its attachment to the undersurface of the diaphragm (Fig. 1). The "bare area" of the liver was thereby exposed and drainage was established by the subcostal abdominal route.

The benefits provided by drainage of the perihepatic space are many. By providing a continuous avenue of escape for wound debris, drainage prevents: (1) bile peritonitis, (2) bile pleuritis, (3) empyema, and (4) subphrenic abscess. An excellent medium for bacterial growth and abscess formation is furnished by the retention at the site of the hepatic wound of necrotic tissue, bile, blood, and exudate. Drainage thwarts the accumulation of such material and thus discourages infection and abscess formation.

It is often difficult to recognize the extent of injury to an organ by inspection at the time of the operation. While the tissue surrounding a small-bore seemingly innocent looking missile tract may appear viable and healthy, it may nevertheless be damaged for a considerable distance by the heat and the "percussive effect" of the missile. This is especially true of the liver. Sloughing may occur as late as ten days following wounding (Case 2). Drains, therefore, were left in place for twelve to fourteen days.

Exploration of the peritoneal contents through the right diaphragm is not feasible. Isolated loops of small bowel and a portion of the transverse colon may be brought up into the wound, but a systematic survey is restricted by the bulk of the liver. In those cases where the suspicion of added intraabdominal injury was entertained, the peritoneal cavity was opened by a separate abdominal incision, or by an extension of the anterior limit of the thoracotomy incision across the costal cartilages onto the abdominal wall. The former method of performing the peritoneal exploration was, in our experience, preferable.

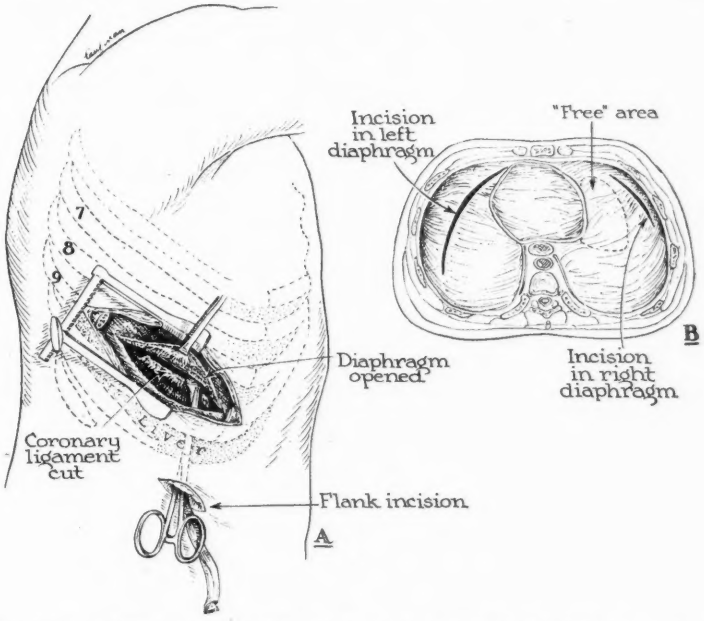

Fig. 1.—*A*, drainage of the perihepatic space in wounds of the liver by means of subcostal drains. Note manner of gaining access to the "bare area" by cutting the coronary hepatic ligament. *B*, diaphragmatic incisions.

The following case report illustrates the management of a thoracoabdominal wound of the right side in which the thorax, diaphragm, and the liver were involved:

CASE 1.—This soldier was wounded by enemy shell-fire May 12, 1944, and was admitted to the hospital three hours later. He was moderately dyspneic, but appeared to be in good general condition. The blood pressure was 90/60, the pulse rate 120 per minute, and the respiratory rate 38 per minute. Examination showed a sucking wound, 4 to 5 cm. in diameter, of the right anterior thoracic wall in the region of the fifth costal cartilage. This had been previously sealed with a petrolatum gauze dressing in a battalion aid station. The foreign body could be palpated as it lay beneath the skin at the level of the eleventh rib in the posterior chest wall. A right thoracentesis was done and 300 c.c. of blood obtained. He was given a transfusion of 500 c.c. of citrated whole blood. Six hours after admission, the blood pressure remained sustained at 105/80 and the pulse rate at 100 per minute. He was then moved for

radiographic examination (Figs. 2*B* and 2*C*), following which he was taken to the operating tent. Premedication consisted of morphine sulphate (gr. 1/6) and atropine sulphate (gr. 1/150 given intravenously fifteen minutes before anesthesia was induced.

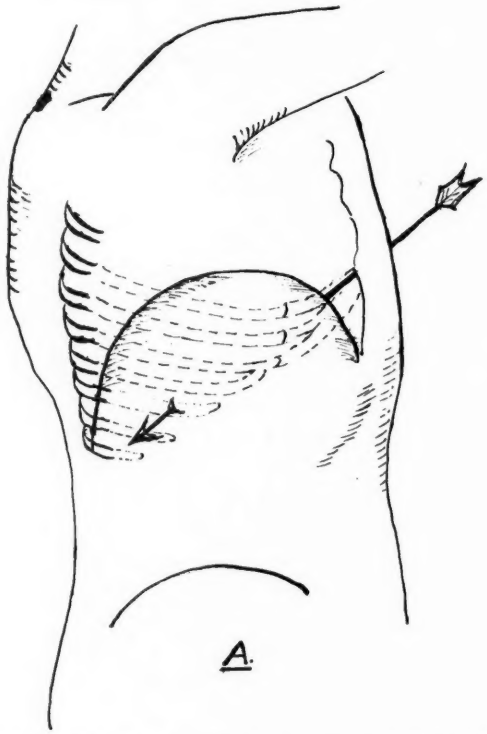

Fig. 2*A*.—(Case 1.) Diagram showing course of the missile.

Under endotracheal ether anesthesia the thoracic wound was excised. A finger was introduced into the right pleural cavity through this opening and a perforation in the diaphragm was felt. A thoracotomy was then performed through the periosteal bed of the ninth right rib. Two perforations of the diaphragm were found, one in its anterior portion through which the missile had entered the abdominal cavity, and one in the posterolateral portion where the projectile left the peritoneal cavity to re-enter the chest. The projectile, in its path, had traversed the middle and lower lobes of the right lung, which contained hematomas. Several rib fragments were removed from the lung where they were embedded. The diaphragm was opened by joining the two wounds with a laterally bowed incision. A perforating wound of the liver was found with large rents radiating from the orifices of the tract. A stab wound was made in the right subcostal region and two penrose wick drains were inserted to drain the posterior subphrenic space and the damaged area of the liver. The diaphragm was tightly closed with interrupted silk sutures. The foreign body was removed from the posterior thoracic wall and the musculature of the region debrided and sutured to prevent sucking. The thorax was closed after the insertion of an intercostal tube for closed drainage. Bronchoscopy was done upon removal of the endotracheal tube. The patient received 1,000 c.c. of citrated whole blood during the operation.

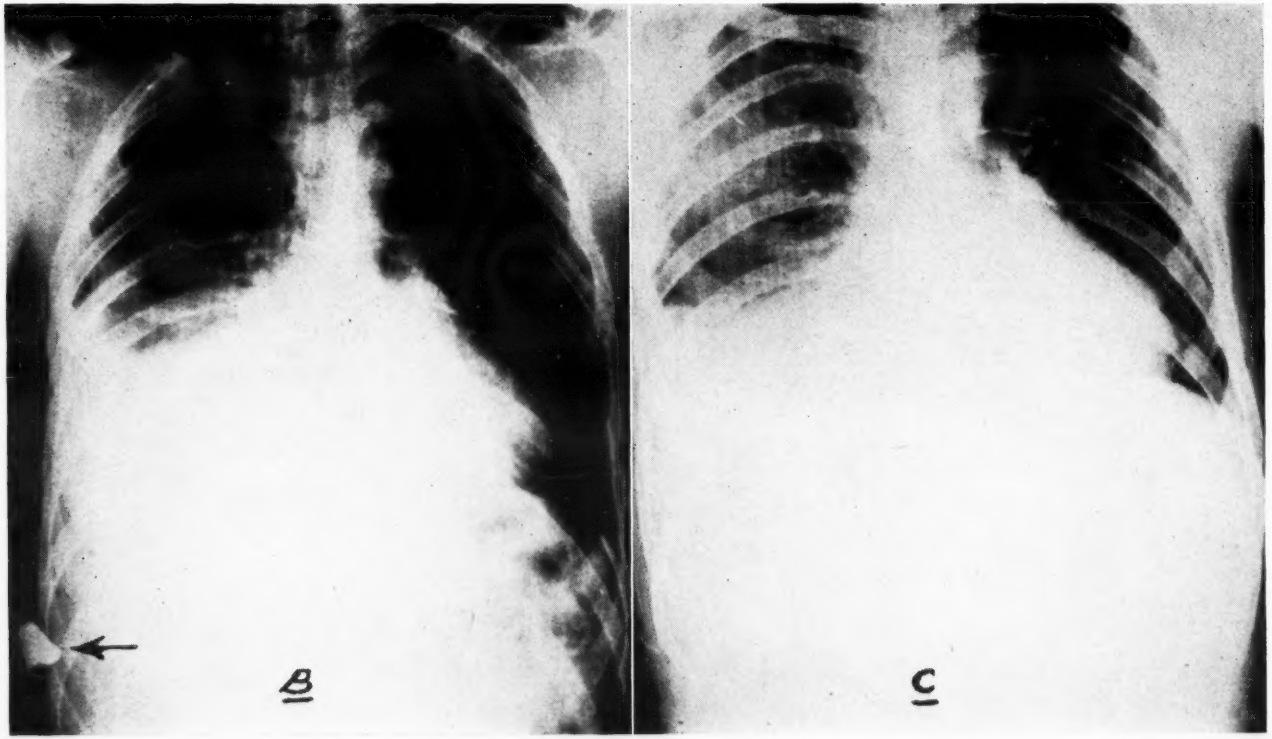

Fig. 2*B*. Fig. 2*C*.

Fig. 2*B*.—Preoperative roentgenogram. The missile has lodged in the subcutaneum after having transversed the right thorax, diaphragm, and liver.

Fig. 2*C*.—Postoperative film after transdiaphragmatic insertion of subcostal drains.

The patient drained large amounts of bile-stained material until his fifth postoperative day, at which time the daily quantity began to lessen. His convalescence was otherwise uneventful, and he was evacuated May 22, ten days after admission, to a general hospital, with the subcostal drains in place. The right lung was completely re-expanded. He received penicillin therapy from the time of his admission until the day he left the hospital.

The value of drainage is demonstrated by the large quantities of bile which escaped postoperatively. Had drainage not been instituted, serious sequelae resulting from the retention of bile undoubtedly would have occurred.

The following case report is included because it emphasizes the value of permitting the subcostal drains to remain in place twelve to fourteen days.

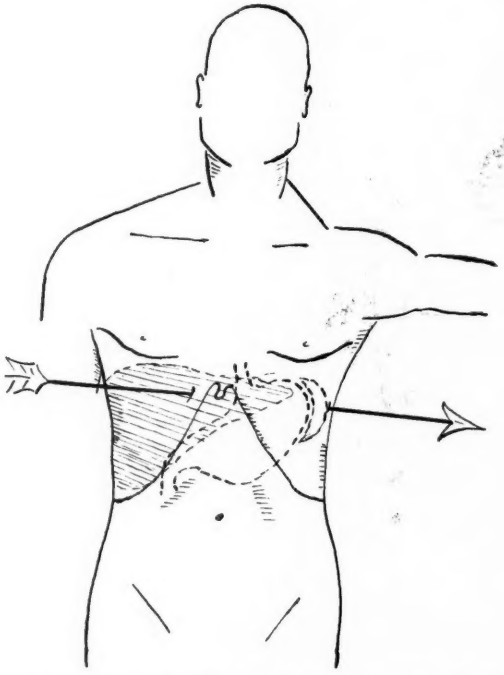

Fig. 3.—(Case 2.) Diagram showing course of the missile. There were perforating wounds of the right diaphragm, liver, stomach, spleen, and the left diaphragm, through which the projectile entered to traverse the left pleural cavity.

CASE 2.—A 42-year-old Italian civilian was accidentally shot by small-arm fire Sept. 8, 1944, and was admitted to the hospital forty-five minutes later. The bullet had entered the right thorax just above the costal arch at the seventh interspace in the midclavicular line, and had exited from the left thorax at the tenth interspace in the midaxillary line (Fig. 3). He was in a semiconscious state and could be aroused only with difficulty. His skin was pale, cold, and clammy. The pulse was barely perceptible and too rapid to be counted. No blood pressure could be obtained. His abdomen was rigid and silent to auscultation. The left side

of the chest was dull to percussion and the breath sounds were suppressed. Examination of the right side of the chest showed nothing remarkable. A left thoracentesis was done and 300 c.c. of blood and 400 c.c. of air were obtained. A Levine tube was passed and the stomach emptied. Seven hours following admission, after he had received 1,000 c.c. of citrated whole blood and 500 c.c. of plasma, the blood pressure was 80/60 and the pulse rate 120 per minute. It was felt that the patient had reached the best possible level of recovery at this time and that nothing was to be gained by further resuscitative treatment. Accordingly, after roentgenographic examination, he was taken to the operating tent. The radiographic films showed a 30 per cent collapse of the left lung and the presence of a hemopneumothorax. There was gas visible under the right diaphragm.

Because of the nature of the wound, which involved both sides of the chest as well as the abdomen, it was decided to explore the peritoneal cavity. Under endotracheal ether anesthesia the abdomen was opened by a left rectus incision. The peritoneal cavity contained approximately 1,000 c.c. of free blood. There was a small perforation of the right diaphragm at its origin from the costal arch, but it did not suck with respiration. The liver contained a small wound of entrance on the upper surface of the right lobe and a similar wound of exit on the under surface of the left lobe. There were no fissures or rents and the injury to the liver seemed minimal. The bullet had traversed the stomach and the spleen and entered the left chest through a small perforation in the left diaphragm. The spleen was extirpated and the wounds of the stomach and both diaphragms were sutured. Before closure, the abdominal cavity was drained through subcostal incisions placed in the flanks on either side. An intercostal tube for the purpose of closed drainage was inserted into the left pleural cavity. The patient received an additional 1,000 c.c. of citrated whole blood during the surgical procedure. At the conclusion of the operation the blood pressure was 100/75 and the pulse rate 110 per minute.

The patient's immediate postoperative course was satisfactory. The intercostal tube drained 100 c.c. of blood during the first twenty-four-hour period. It was removed on the following day when radiographic examination showed complete expansion of the left lung. The subcostal stab wounds drained small amounts of bile-stained material until Sept. 12, the third postoperative day, when drainage ceased. On Sept. 18, six days later, ten days after wounding, he suddenly complained of a severe constricting pain in the lower midsternal region. The pulse and respiratory rates rose to 120 and 32 per minute respectively, and the blood pressure dropped to 90/60. The abdomen remained soft to palpation but was tender in the midepigastric region. Clinical examination of the chest revealed nothing remarkable. It was thought that a coronary occlusion, or a pulmonary embolism had occurred. He was given oxygen by intranasal catheter and was sedated with morphine. But on the morning of the following day the bedding was found saturated with bile-stained fluid! This was found to be coming from the left subcostal drain. Profuse drainage continued until September 21. The patient's condition improved immediately after drainage occurred. The drains were removed on September 24, fifteen days after operation, and the patient was discharged from the hospital on September 30. He had received routine penicillin therapy.

It seems clear that the explanation for the patient's acute clinical episode on the ninth postoperative day was a sloughing of the liver with a sudden release of bile into the peritoneal cavity. The liver had evidently suffered a greater degree of damage than was apparent to the eye at the time of the operation. Sloughing of necrotic liver substance may occur up to ten days following the injury and result in the serious consequences previously mentioned if drainage has been discontinued.

Wounds of the left diaphragm: Unlike the right side, adequate exposure of the contents of the upper abdomen may be obtained through the left diaphragm.

Indeed, we feel that this method of approach exposes the stomach, spleen, left kidney, left adrenal, and the splenic flexure of the colon with greater ease than through the abdomen. This is especially true in the asthenic type of individual with long chest and narrow costal arch, where these organs are accessible with more than the usual amount of difficulty from the abdominal side. In addition, the transdiaphragmatic route is preferred in approaching wounds involving the left chest and the upper abdomen because it affords access to both thoracic and abdominal cavities in a single procedure, because perforations in the diaphragm are more readily found and sutured upon its pleural than upon its peritoneal surface, and because it affords the opportunity to cleanse adequately the pleural cavity of blood and the spillage of perforated abdominal viscera which may have been sucked into the chest through the diaphragmatic wound.

The stomach is easily accessible through the diaphragm and may be explored from the cardia to and including the duodenal bulb. The posterior wall of the stomach is exposed by dividing the gastrocolic ligament, or by lifting the omentum and freeing it from the traverse colon to which it is loosely adherent, thus entering the lesser omental bursa. Further exposure may be obtained by continuing the division along the gastrosplenic ligament.

The stomach requires a diligent and complete examination of its anterior and posterior surfaces, and its lesser and greater curvatures. Small perforations are easily overlooked, especially along the lesser curvature where the gastric musculature constricts the opening in a sphincterlike fashion and the subserosal fatty deposits tend to conceal the puckered wound. The disclosure of a single perforation prompts a systematic perusal of the organ for an accompanying wound of exit or entry.

The colon is available for inspection along its transverse, splenic flexure, and proximal descending portion. Individual variations in the mobility of the sigmoid and the distal portion of the descending colon makes these regions more or less accessible. Perforations were treated after exteriorizing the involved loop through a small abdominal incision.

The small intestine is amenable to manipulation and repair through the left diaphragm, and may be inspected in continuity from the duodenojejunal flexure to within a short distance of the terminal ileum. Again, individual variation in the mobility of the cecum sometimes made exposure of the terminal ileum and cecum possible.

When an exploration of the abdomen through the left diaphragm was anticipated, thoracotomy incision was made through the bed of the eighth or ninth rib. If the wound entering or exiting from the chest was located in this region, the incision was made by an extension of the wound. In a few instances, when insecurity was felt because of the possible existence of other lesions in the lower peritoneal cavity, an abdominal exploration was done through a separate abdominal incision.

The first of the following two cases illustrates the management of a patient who was injured by a missile which traversed the left thorax, diaphragm, and abdomen. The second case is presented to show the advantage of the transdiaphragmatic approach in a wound which involved the left thorax and left

upper abdominal quadrant in an individual of the asthenic type. In this instance a comparison is afforded as to the relative advantages since both the abdominal and the thoracic routes were used in separate operative procedures.

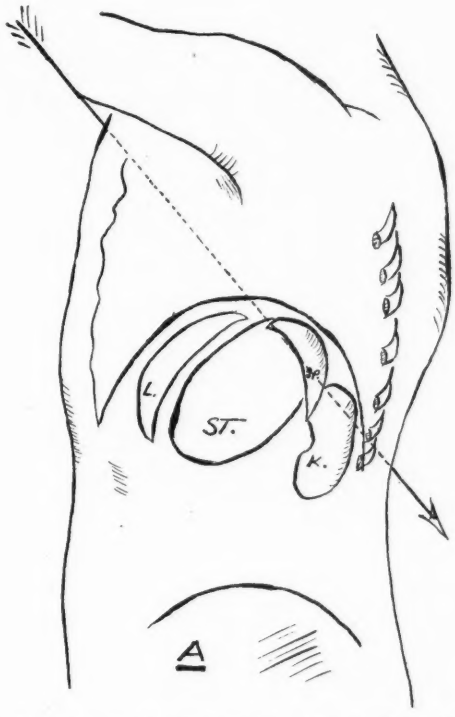

Fig. 4A.—(Case 3.) Diagram showing course of the missile, which traversed the left pleural cavity and abdomen to perforate the upper and lower lobes, diaphragm, stomach (ST), spleen, (SP), and kidney (K).

CASE 3.—This soldier was hit by a sniper's bullet April 16, 1945, and arrived at the hospital approximately eight hours later. The bullet entered the left side of the chest through the second rib at the midclavicular line and made its exit through the left posterior eleventh intercostal space (Fig. 4). He was dyspneic, pale, and in a semiconscious state. On examination, the abdomen was found to be somewhat rigid and tender to palpation. Breath sounds were absent over the left thorax. The blood pressure was 70/30, the pulse rate 140 per minute, and the respiratory rate 42 per minute. He was given oxygen by intranasal catheter and 500 c.c. of plasma intravenously. Blood for transfusion, unfortunately, was not immediately available. A left thoracentesis was done, and 500 c.c. of blood was withdrawn. This was citrated and returned to the patient's circulation. A Levine tube was passed and the stomach emptied. Three and one-half hours after admission, the blood pressure remained sustained at 100/75. He was then examined radiologically, following which he was taken to the operating tent.

From the course of the missile through the body, it seemed likely that the bullet had perforated the diaphragm after traversing the left thoracic cavity. He was given morphine

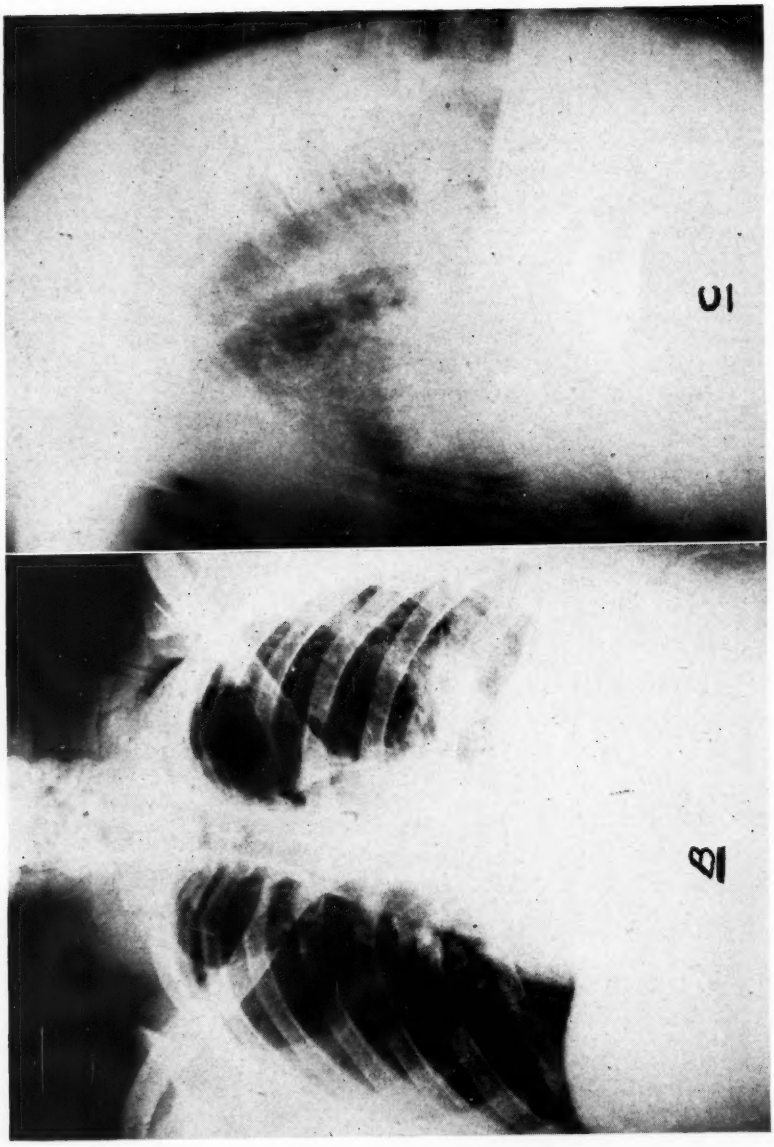

Fig. 4B.

Fig. 4C.

Figs. 4B and 4C.—Preoperative roentgenograms. Note perforating wound of the anterior portion of the second rib.

sulphate (gr. 1/6) and atropine sulphate (gr. 1/150) intravenously, and ether anesthesia was induced fifteen minutes later. The wounds of the thoracic wall were debrided initially. During this procedure the posterior wound commenced to suck. A finger was introduced into the pleural cavity through the opening and a perforation in the diaphragm felt. The soft tissue of the chest wall was sutured over this opening into the thoracic cavity to prevent sucking and an elective incision was then made through the bed of the ninth rib. The pleural cavity contained approximately 1,000 c.c. of liquid and clotted blood. This was scooped out, strained,

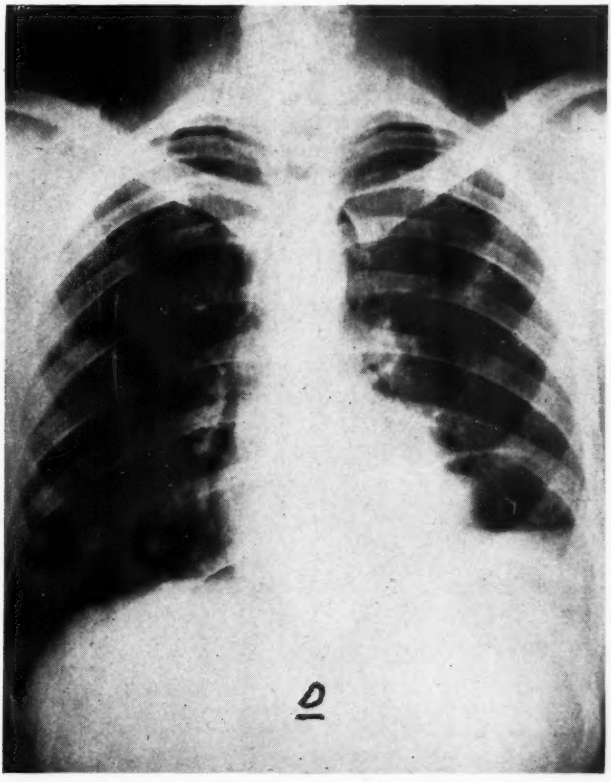

Fig. 4*D*.—Postoperative film after transdiaphragmatic splenectomy, nephrectomy, and repair of the stomach.

and citrated. It was possible in this way to obtain 600 c.c. of blood, which was returned to the patient. The left upper and lower lobes contained hematomas, but there was no bleeding from the pulmonary wounds. The diaphragm presented a perforation in its dome where the missile had entered and a wound in its posterior portion at the costal attachment where it had made its exit. The diaphragm was opened. There was free blood in the peritoneal cavity. The spleen contained a perforating wound with many radiating fissures. It was removed. There was a subserosal hematoma at the fundus of the stomach which partially obscured a small perforation. To completely view the posterior gastric wall, the lateral portion of the gastrocolic ligament was divided and the stomach was rotated. An accompanying wound was found. Both gastric wounds were sutured. The posterior parietal peritoneum

contained a perforation and was tense and discolored. It was incised to find a large retroperitoneal hematoma which was evacuated. Inspection of the left kidney revealed a perforating wound in the superior pole with many radiating fissures. A nephrectomy was done, following which the nephritic space was drained through a stab wound in the flank. The posterior parietal peritoneum was then closed and the margins of the diaphragmatic incision were approximated with interrupted silk sutures. The thorax was closed after inserting an intercostal tube for the purpose of closed drainage. Bronchoscopy was done after the removal of the endotracheal tube. The patient received an additional 500 c.c. of plasma. The blood pressure at the completion of the operation was unchanged.

The patient's recovery was uneventful. The intercostal tube was removed on the second postoperative day, at which time radiologic examination showed the left lung to be completely expanded. The patient was walking on the sixth postoperative day and was evacuated to the rear on April 27, eleven days following wounding. Penicillin had been started upon admission and was continued in the usual dosage throughout his hospital stay.

The above case illustrates two points in merit of the transdiaphragmatic route. First, it shows the latitude that is afforded with regard to the number of organs that may be approached. In this instance, the spleen and left kidney were removed, the stomach sutured, the diaphragm repaired, the lung inspected, and the pleural cavity cleansed. Second, it demonstrates the early date at which patients so treated may be gotten out of bed without the fear of wound dehiscence and consequences which attend a laparotomy. The advisability of autotransfusion in cases with suspected thoracoabdominal wounds may rightly be questioned. In the above instance, however, no alternative was offered because of the absence of blood for transfusion.

CASE 4.—A German officer was wounded by rifle fire April 28, 1945, and was admitted to the hospital April 30, thirty hours later. The bullet had entered the right side of the thorax just above the costal arch at the seventh intercostal space in the midclavicular line, and had made its exit from the left thorax at the tenth interspace in the posterior axillary line. The paient was a tall, thin, long-chested individual of the asthenic type. He was mentally alert, but appeared to be ill and dehydrated. The blood pressure was 100/80; the pulse rate 130 per minute; the respiratory rate 40 per minute; and the temperature 101.8° F. The abdomen was rigid and tender to palpation. The left thorax was dull to percussion and the breath sounds were suppressed. Examination of the right chest was not remarkable. A left thoracentesis yielded 250 c.c. of dark blood. He was given 1,000 c.c. of 5 per cent glucose in physiological solution of sodium chloride and 500 c.c. of citrated whole blood. A levine tube was introduced and the stomach emptied. Roentgenograms (Fig. 5) showed a left hemothorax, and dilated loops of bowel arranged in a ladderlike pattern.

Seven hours after admission, thirty-seven hours after wounding, under endotracheal anesthesia, the patient's abdomen was opened by a left subcostal incision. The peritoneal cavity contained free gastric contents and the serosal surfaces of the bowel were matted with a shaggy, plastic exudate. The tissues were edematous and friable. A small perforation in the undersurface of the right diaphragm at its costal attachment was found. The missile had traversed the liver and entered the stomach at the lesser curvature, which contained a partially sealed wound. This was sutured. An accompanying wound of the stomach could not be located on its anterior surface. Therefore, the lesser peritoneal sac was entered and free gastric contents were found issuing from a wound high in the posterior wall of the stomach in the region of the cardia. Difficulty was encountered in exposing the wound because of the deep recess formed by the costal arch. Closure of the gastric wound was ultimately accomplished. The omental bursa was drained through a stab wound in the left flank. A perforation in the left diaphragm could not be found. After closure of the abdomen, an intercostal tube was inserted into the left pleural cavity for closed drainage. Blood in the amount

of 300 c.c. was immediately obtained. The patient received an additional 500 c.c. of citrated whole blood during the surgical procedure. The blood pressure at the conclusion of the operation was 100/75.

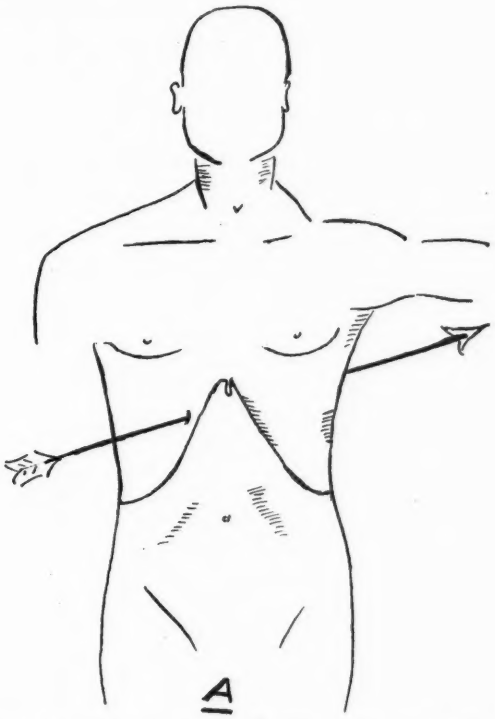

Fig. 5A.—(Case 4.) Diagram showing course of the missile, which perforated the right diaphragm, liver, stomach, spleen, and the left diaphragm to enter and traverse the left pleural cavity.

The patient's behavior throughout the week that followed was uncooperative and insubordinate. He repeatedly withdrew the Levine tube which had been inserted for the purpose of continuous gastric suction, and he stole food and liquids from neighboring patients. His general condition, nevertheless, remained satisfactory. The blood pressure was 110/80 to 120/80; pulse rate 100 per minute, respiratory rate 24 to 26 per minute, and temperature 99 to 100° F. On May 2, the intercostal tube was removed, and radiographic films showed the left lung to be completely expanded. On May 6, the sixth postoperative day, it was noticed that the drainage from the stab wound in the left flank became thin and copious. The development of a gastric fistula from the posterior wound of the stomach was suspected. Methylene blue given by mouth appeared upon the dressing within a few hours. A Levine tube was reintroduced and a determined effort made to keep the stomach decompressed in the hope that the fistula might close spontaneously. His nutrition was supported by the parenteral administration of fluid, blood, electrolytes, and plasma. However, methylene blue, given orally on May 11, again reappeared on the dressings.

It was decided that surgical closure of the fistula was necessary. On May 12, twelve days after the previous operation, under endotracheal anesthesia, the left pleural cavity was opened through the periosteal bed of the eighth rib and the diaphragm exposed. A small,

well-sealed perforation was found in its posterolateral portion. The peritoneal cavity was opened by incising the diaphragm. The superior pole of the spleen was raw, necrotic, and covered with a shaggy exudate (it had been injured by the passage of the missile). The spleen was removed. The lesser peritoneal sac was opened by freeing the stomach from the posterior abdominal wall to which it had become adherent. The fistulous gastric opening was then adequately exposed. The gastric wound was "trimmed" and sutured. The margins of the diaphragmatic incision were approximated and the chest closed after the insertion of an intercostal tube for closed drainage. The patient received 500 c.c. of citrated whole blood during the surgical procedure. His blood pressure remained unchanged.

Fig. 5*B*.—Preoperative roentgenogram. Note the dilated loops of bowel due to peritonitis of ileus.

The patient's postoperative course was uneventful save for the late development of what was taken to be an infection of the incision. The intercostal tube was removed on the second postoperative day when roentgenographic examination showed the left lung to be completely expanded. The stomach wound remained closed, and by May 21, nine days after operation, he was taking a soft diet. The drain in the left flank, which had been allowed to remain from the time of the first operation, was removed. On the eleventh postoperative

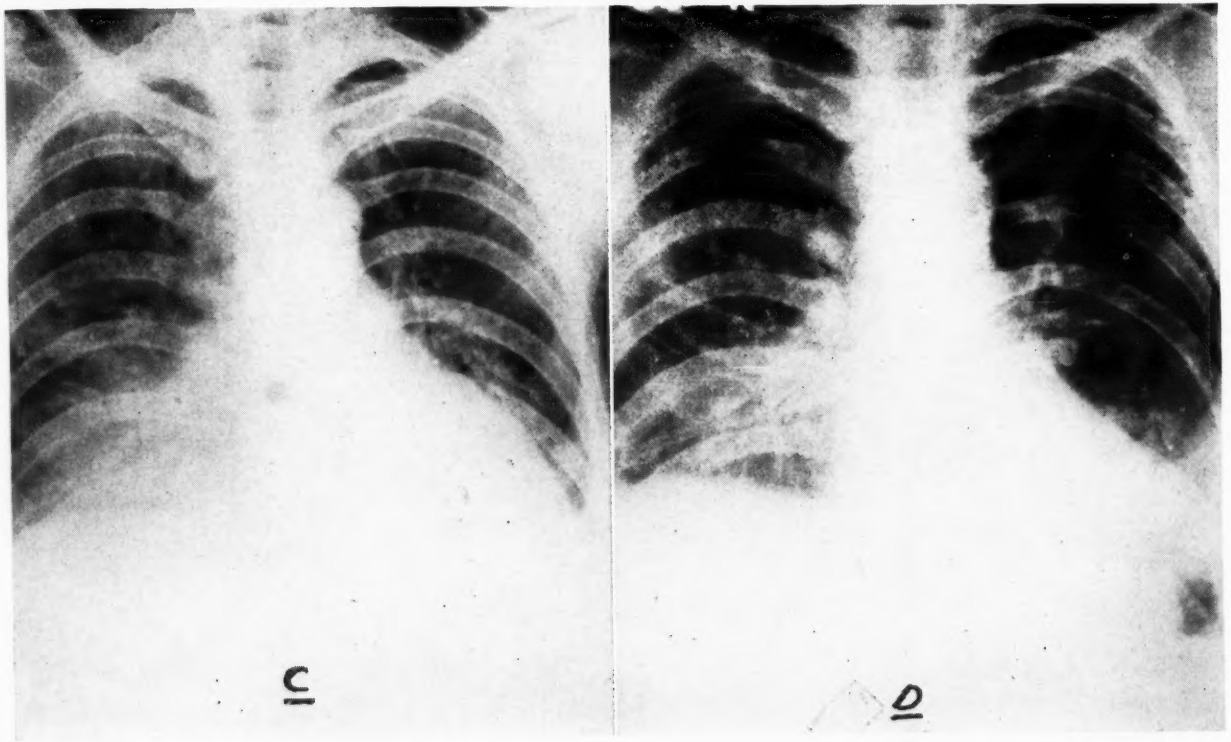

Fig. 5*C*. Fig. 5*D*.

Fig. 5*C*.—Roentgenogram taken after laparotomy.
Fig. 5*D*.—Film taken twelve days later, after reoperation by the transdiaphragmatic route to close the gastric fistula.

day he developed a daily temperature elevation ranging from 99 to 100° F. The midportion of the thoracotomy wound was indurated, and upon separating, a portion of the wound approximately 20 c.c. of thick yellow pus escaped. On May 30, eighteen days after operation, he was evacuated to a general hospital although the wound continued to drain intermittently. He was later seen at a general hospital, where it was found that the purulent discharge which issued from the wound communicated by a sinus tract with a left subphrenic abscess. This was drained and he subsequently recovered and was discharged from the hospital on July 1.

In retrospect, it appears that the original abdominal operation performed upon this patient would not have been done had the structure of his thoracic cage been recognized. That difficulty would be experienced in gaining access to the left upper abdominal quadrant of this asthenic individual should have been foreseen. We feel that if this patient's viscera had been originally approached by the transdiaphragmatic route, adequate exposure of the high-lying gastric lesion would have been obtained without the difficulties met in the abdominal approach, and a more secure closure would have been accomplished. Moreover, visualization from above would have disclosed the perforation in the diaphragm and the injury to the spleen.

There was a total of thirty-five patients with thoracoabdominal wounds. The right diaphragm was perforated in twenty patients, the left in fifteen. There were two deaths, a mortality of 5.7 per cent. In both fatalities the wound involved the right diaphragm. One death occurred on the fifth postoperative day and was caused by bilateral bronchopneumonia. The second death occurred on the patient's sixth postoperative day and was due to uremia. This patient was in a prolonged state of shock before operation, and he remained anuric throughout the postoperative period.

(2) *Large Intrapulmonary and Intrapleural Foreign Bodies.*—The need for *early* thoracotomy for the removal of intrathoracic foreign bodies is a subject upon which there is considerable difference of opinion. The pulmonary parenchyma tolerates the presence of small and medium-sized foreign bodies with little reaction and its great vascularity confers a high degree of resistance to infection. Missiles of this size which had lodged in the lung were not removed in the forward evacuation hospitals. The management of such wounds was "conservative." It consisted of debridement and the control of bleeding in the wound of the chest wall. If a sucking traumatic aperture in the thoracic cage was present, closure was performed. Postoperative daily thoracenteses were done in an effort to obtain complete re-expansion of the lung as rapidly as possible. Such supplementary procedures as bronchoscopy, oxygen administration, procaine injection of intercostal nerves, and transfusions of blood were usually needed to restore completely the cardiorespiratory equilibrium. Within five days the patient was ready for transportation to a general hospital. Indeed, at this stage he was frequently ambulatory. The general hospital now received a stabilized patient, far better able to withstand a thoracotomy for the removal of the retained foreign body than the freshly wounded battle casualty.

It is the contention of some surgeons, because of the success that had been obtained with this conservative regimen, that the early removal of any foreign

body should not be done at an evacuation hospital; that the primary consideration here is the restitution of cardiorespiratory balance, and that the development of infection may be held in abeyance until the patient's arrival at a general hospital. The operation for its extraction is then left to the surgeons of the general hospital, where their decision may rest on factors other than that of infection.

While we are in accord with these principles, our experience, however, leads us to conclude that the decision to refrain from removing a missile depends upon its size. The likelihood of infection with missiles of small or moderate size is not great and they may be allowed to remain with safety provided that the pleural cavity is emptied of blood and air, and the pleural space obliterated by rapid expansion of the lung. We believe, however, that large, irregularly shaped metallic fragments which lodge within the thoracic cavity should be removed early at the evacuation hospital. The basis for this contention rests upon the established principle that the tissue's ability to ward off infection is the result of its immunity versus the dose of bacterial inoculation (and virulence). Applying these factors to war wounds, an analogy may be drawn: immunity is to tissue damage as dose is to quantity of foreign material brought into the wound by the missile. The amount of tissue destruction and the quantity of foreign material that is carried into the thorax with metallic fragments of moderate size (2.5 × 2.5 cm.) is such that the balance (with the help of antibiotics) is usually weighted in favor of resisting the spread of infection. Larger shell fragments of irregular shape, however, tend to upset the precarious equilibrium. This is so because of the greater disruption of tissue and because of the implantation of more massive amounts of alien material. It was usual to find a missile of this size wrapped within a large patch of the soldier's clothing. Nor was it uncommon to find rib fragments and pieces of intercostal muscle and periosteum imbedded in the lung. These alien materials serve not only as bacterial inoculating agents, but as a continuing source of stimulation leading to the production of large amounts of bronchial secretions. The hazard of early infection in such cases, in spite of the use of penicillin, far exceeds the risk entailed in an early thoracotomy for the removal of the missile.

The following two cases illustrate the management of patients with large intrathoracic metallic fragments. In the first case a large missile was removed by thoracotomy with an uncomplicated recovery. In the second, delayed removal of the missile led to a series of complications which, in our opinion, would have been avoided by its early removal.

CASE 5.—This soldier was wounded by enemy shell fire Feb. 11, 1944, and was admitted to the hospital eight and one-half hours later. He did not appear to be in critical condition, although he had had several small hemoptyses. The blood pressure was 105/75; the pulse rate 100 per minute, and the respiratory rate 32 per minute. Examination disclosed a single large wound in the deltoid region of the left arm. There was no wound of exit and roentgenographic films of the left arm and axilla did not show a foreign body. It was suspected that the missile had traversed the left arm and axilla, to pierce and lodge in the thorax. This was confirmed by further films (Fig. 6). The foreign body was seen in the midlung field, and measured 3 × 4 cm. in size. It was considered too large a missile to be allowed to remain.

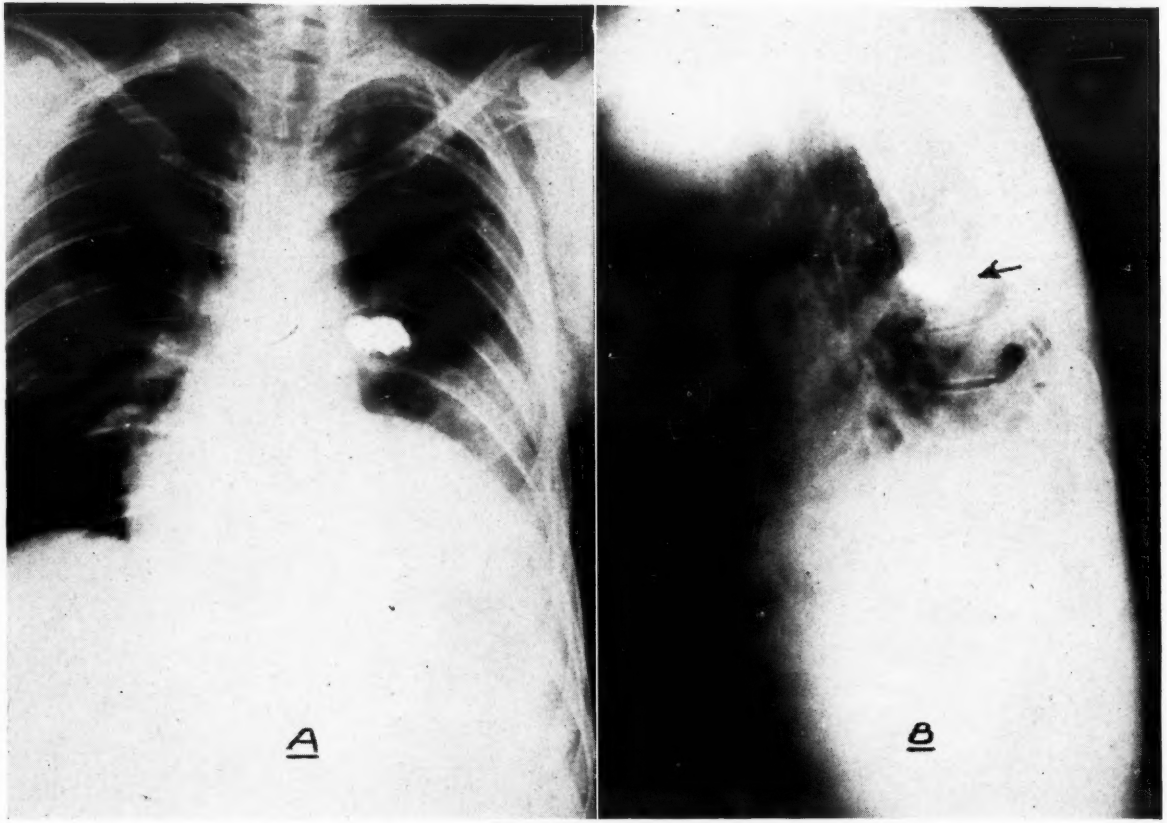

Fig. 6A. Fig. 6B.

Figs. 6A and 6B.—(Case 5.) Preoperative roentgenograms showing metallic fragment lodged in the superior division of the left lower lobe.

On February 12, three and one-half hours after admission, under endotracheal ether anesthesia, a thoracotomy was done through the bed of the left sixth rib. The metallic fragment was found in the superior division of the left lower lobe and was encased in a wrapping of woolen cloth. Upon its removal from the lung substance, active bleeding occurred from several intrapulmonary vessels which had been cut by the missile. These were ligated, and the traumatic cavity within the lung was obliterated with sutures of fine chromic

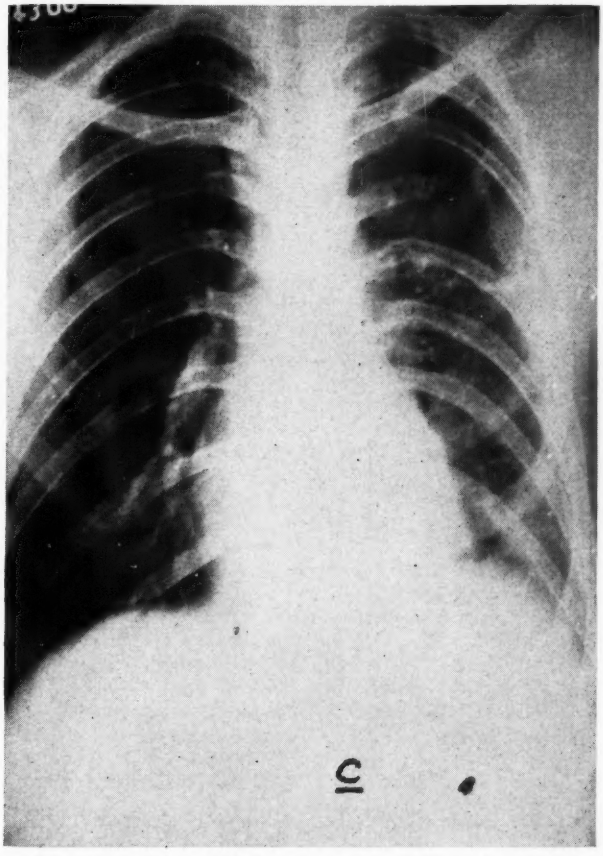

Fig. 6*C*.—Postoperative film following thoracotomy and removal of the missile.

catgut. The lung was then expanded by positive pressure and the thorax closed after the insertion of an intercostal tube for closed drainage. The wounds of the left arm and axilla were debrided. Bronchoscopy was performed after the endotracheal tube was removed and the tracheobronchial tree cleansed. The patient received 500 c.c. of citrated whole blood during the surgical procedure. There was no alteration in the blood pressure or the pulse rate at the completion of the operation.

The patient made an uneventful recovery and was evacuated to a general hospital on February 22, ten days after operation. He received sulfadiazine therapy from the time of his admission to his evacuation. He was seen two weeks later at the general hospital. A

secondary closure of the wound of the arm had been done. He was ambulatory, had no complaints, and was classified to resume-duty status after a period of rehabilitation.

CASE 6.—This soldier was wounded by enemy shell fire Nov. 29, 1944, and was admitted to the hospital approximately four and one-half hours later. He was alert, mildly dyspneic, and complained moderately of pain. The blood pressure was 100/70; the pulse rate 120 per minute, and the respiratory rate 34 per minute. Examination disclosed a large, nonsucking wound in the left posterior thoracic wall at the level of the fifth rib. Radiographic films showed a large (3 × 4 cm.), irregularly shaped, intrapulmonary metallic fragment and a small hemopneumothorax (Fig. 7, *A*). Aspiration of the left pleural cavity yielded 150 c.c. of blood. He was given 500 c.c. of citrated whole blood, and three and one-half hours after admission, eight hours after wounding, the wound of entrance was debrided under endotracheal ether anesthesia.

The postoperative course for the succeeding twenty-four hours was uneventful. Aspiration of the left pleural cavity yielded 250 c.c. of blood. On the second postoperative day, however, his temperature rose to 101° F. A left thoracentesis yielded 150 c.c. of bloody fluid which had the suggestion of a faint odor. A transfusion of 500 c.c. of citrated whole blood was given. The following day the patient was considerably more toxic, and the fluid obtained by aspiration had a definite odor. An intercostal tube was inserted into the pleural cavity and 800 c.c. of thin, dark, foul fluid and gas were evacuated into a water-seal. A transfusion of 500 c.c. of citrated whole blood was given.

Following the institution of closed drainage the patient's condition gradually improved. Supplementary treatment consisted of transfusions of whole blood and the continued administration of penicillin, which had been started at the time of his admission to the hospital. His empyema cavity (Fig. 7, *B*) continued to drain 100 c.c. daily of foul, serous, brown fluid which soon changed to frank pus. A radiographic film taken on December 7 showed that the intrathoracic metallic fragment had worked itself loose from the lung and lay in the pleural cavity (Fig. 7, *C*). He continued to have a low-grade fever, but by December 16, seventeen days following debridement, his condition was deemed sufficiently improved to withstand further operative treatment. Accordingly, a thoracotomy was done for the purpose of removing the foreign body and decorticating the lung.

The thorax was opened through the bed of the left sixth rib. A smooth-walled empyema cavity was found. The upper and lower lobes of the left lung were decorticated of their investing layer of organizing, fibrinous, pyogenic membrane. The metallic fragment was found encapsulated within a small abscess cavity in the posterior costophrenic sinus. Upon removal, it was seen to be encased within a wrapping of woolen cloth. Slivers of rib 2 cm. in length and small pieces of woolen cloth were removed from the superior division of the left lower lobe, the original site of lodgment of the missile. The lung was then expanded and the thorax closed after the insertion of two rubber tubes for the purpose of providing closed drainage. The apex of the pleural cavity was drained through the second anterior intercostal space, and the base through the eighth interspace in the posterior axillary line. The patient received 1,000 c.c. of citrated whole blood during the surgical procedure.

The patient's convalescent period was uneventful. He remained afebrile and was evacuated in an ambulatory condition to a general hospital on January 4, nineteen days after thoracotomy, thirty-six days after admission. Radiographic examination (Fig. 7, *D*) at the time of his discharge showed the persistence of a small, basal pleural pocket. In view of his afebrile condition, however, it was hoped that obliteration would occur spontaneously. A follow-up at a general hospital one month later disclosed that the patient had remained fever-free, and that the previously noted pocket had become obliterated.

The above two cases were chosen for presentation because of the similarity of their lesions; yet each was treated differently, thus affording a basis for appraisal. In both cases the foreign bodies were of approximately equal size and were located in analogous situations; namely, the superior division of the

left lower lobe. In the first case, an early thoracotomy was performed and the metallic fragment with accompanying woolen cloth removed. There followed an uneventful postoperative recovery and the patient was evacuated to the rear ten days after operation. In the second case, conservative management was attempted with the occurrence of complications previously described. Ultimate recovery was attained, but only after a hospital stay of thirty-six days, a loss of twenty-six days in evacuability as contrasted with the previous case. It is our opinion that had an early thoracotomy for the removal of the shell fragment and the in-driven foreign material been performed upon this patient when the wound was originally debrided, infection and empyema would have been prevented. Furthermore, there would have been a saving of twenty-six days in hospitalization time.

Thoracotomy for the purpose of removing a foreign body was done in sixteen cases. When it was controversial whether the size of the missile indicated this procedure, the condition of the patient and the extent of the wound in the thoracic cage settled the issue. It was felt that much was to be gained and little was to be lost if a large sucking wound (5 to 6 cm. in diameter) was extended sufficiently to allow for the extraction of the missile and for the removal of debris and blood clots from the pleural cavity.

There exist a group of wounds which occupy a borderline position in regard to classification. We refer to those cases of sucking wounds of such size that the breach in the thoracic cage allowed the introduction of a hand into the pleural cavity. We have elected to include these cases within this category of "thoracotomy for the presence of intrathoracic foreign bodies" because, in essence, a thoracotomy was effected, albeit by traumatic rather than by surgical means, and because, at operation, foreign material was manually removed from the pleural cavity.

There were three deaths in a total of sixteen cases, a mortality of 18.0 per cent. All three occurred in the subgroup previously mentioned, namely, that group in which there was present a "traumatic thoracotomy." One death was due to "shock" and occurred on the operating table; one patient died of uremia on the sixth postoperative day; and one death, on the eleventh postoperative day, was caused by severe bronchopneumonia. This was occasioned by an ineffective cough mechanism because of paralysis of the thoracic and abdominal musculature as a result of an associated spinal-cord injury.

(3) *Missiles in or Traversing the Mediastinum.*—Our experience with wounds of the mediastinal organs is limited because most of such patients either died before reaching the hospital or were detained at a more forward installation. Patients with penetrating wounds of the mediastinum did, however, reach the hospital, but they represent instances in which the heart, great vessels, and the trachea escaped damage by the missile. With these patients our chief concern was directed toward the esophagus, which may be perforated without exhibiting early symptoms.

Wounds of the mediastinum anterior to the portion which contains the esophagus, in which there was no evidence of injury to the trachea or to the

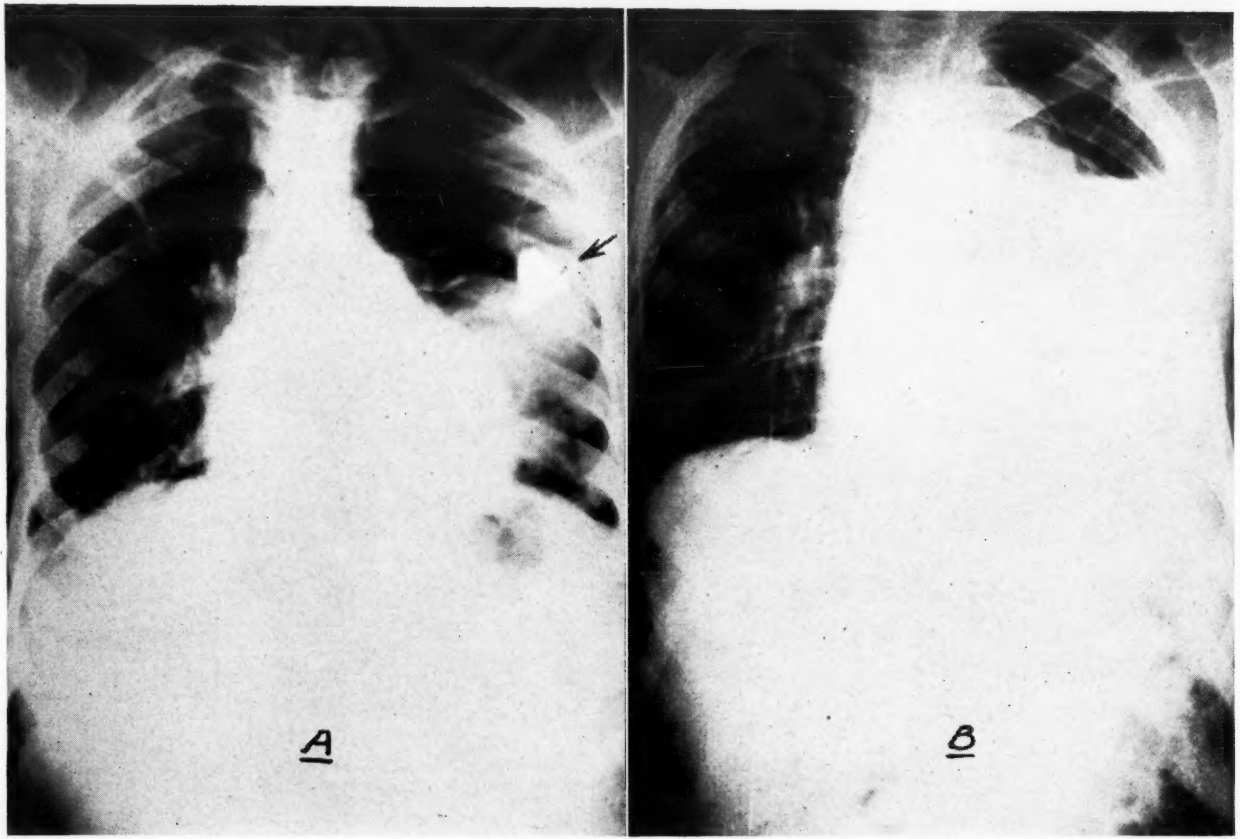

Fig. 7A. Fig. 7B.

Fig. 7A.—(Case 6.) Roentgenogram showing metallic fragment lodged in the lateral portion of the superior division of the left lower lobe.

Fig. 7B.—Three days later, following debridement of the wound of the thoracic wall without removal of the foreign body.

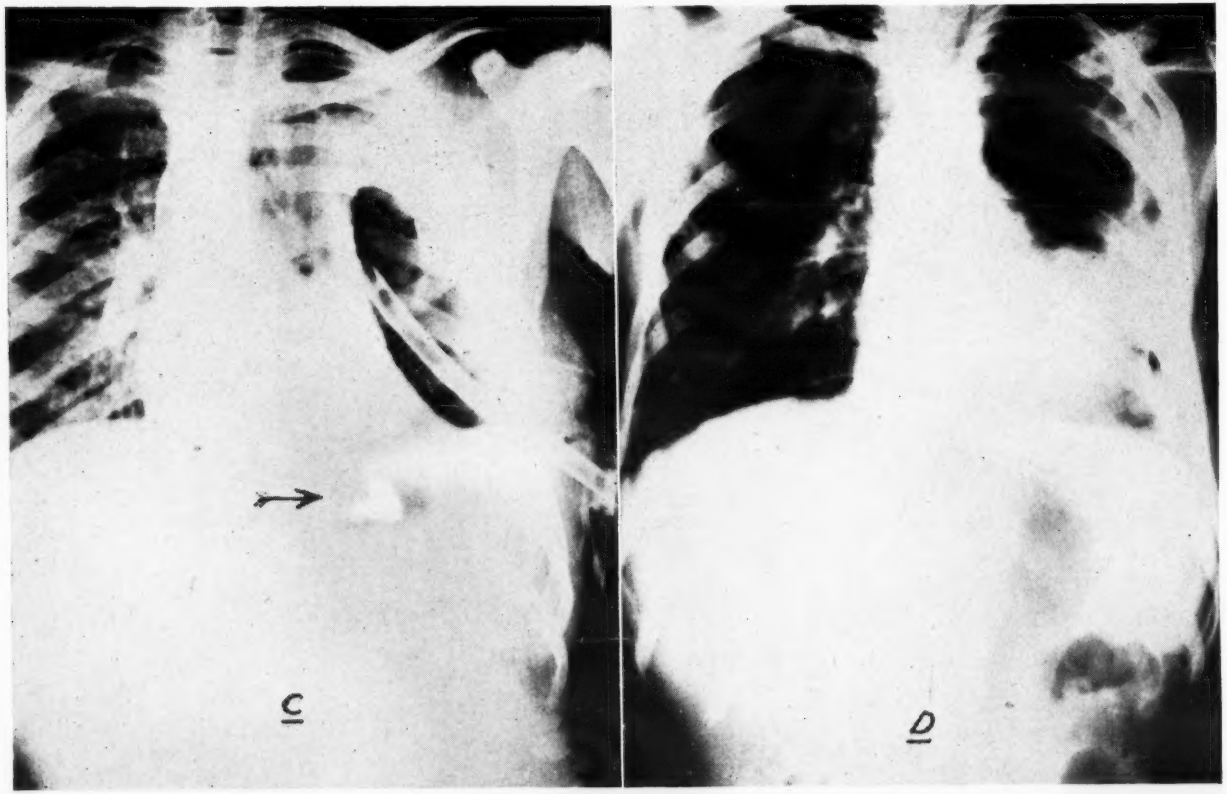

Fig. 7C.

Fig. 7D.

Fig. 7C.—Empyema cavity after institution of closed drainage. Note position of the missile in the posterior costophrenic portion of the pleural cavity, where it gravitated after working loose from the lung.

Fig. 7D.—Roentgenogram ten days following decortication and removal of the foreign body.

great vessels, were treated conservatively by debridement and by closure of the wound of the thoracic wall. The metallic foreign body was permitted to remain within the thorax, unless it was so large and irregular that early infection was feared from the carrying in of clothing.

There was one patient with a perforation of the trachea. However, because of the smallness of the wound, as confirmed by bronchoscopy, and the absence of mediastinal emphysema, conservative management was followed. The patient's recovery was uneventful.

There was one case of a penetrating wound of the heart. A small splinter of metal traversed the patient's right pleural cavity and lung to lodge in the myocardium of the ventricle. Inasmuch as there were no cardiac symptoms and no signs of a hemopericardium, operation upon the heart was deferred and treatment directed toward evacuating the hemothorax and expanding the lung. This was accomplished in three days. He continued to remain free of circulatory signs and symptoms. He was transferred to a general hospital where thorough studies revealed no indication for removing the missile. He was eventually returned to duty.

All eleven cases in which there were penetrating wounds of the anterior mediastinum were treated conservatively and all recovered.

Unlike asymptomatic wounds of the anterior mediastinum, missiles lodging in or traversing the posterior mediastinum require exploration to determine the presence of an esophageal injury. There were five patients with such wounds for which thoracotomy was done. Although there was no case in which a perforation of the esophagus was found, it was felt that exploration was warranted because of the path through, or the location of the missile in the posterior mediastinum. There were no fatalities.

(4) *Wounds of the Large Bronchi.*—A battle casualty with a wound of a bronchus was not usually seen at an evacuation hospital. Our experience with wounds of this nature is, therefore, limited. It must be presumed that most of such patients died upon the battlefield, although in rare instances they have been known to reach a forward hospital. The rapid death caused by such an injury is produced in one or more of the following ways:

1. Asphyxia due to flooding of the tracheobronchial tree with blood aspirated into the bronchus from the pleural cavity, or directly from an adjacent bleeding hilar vessel.
2. Asphyxia due to tension pneumothorax.
3. Mediastinal emphysema with compression of the great veins of the mediastinum.
4. Hemorrhage resulting from injury to an adjacent, large, pulmonary, hilar or systemic vessel.

There was only one case in which the bronchus was suspected of having sustained a wound. This patient entered the hospital two and one-half hours after having received a penetrating wound of the left thorax. Shortly after admission, on being moved from the stretcher to the roentgenographic table, he became rapidly dyspneic and cyanotic. The diagnosis of a tension pneumothorax

was made. A needle was immediately inserted into the left pleural cavity through the second anterior intercostal space, and attached to a water seal. There was an immediate release of air under pressure, as was evidenced by vigorous bubbling in the water bottle. The radiographic films showed a left pneumothorax and the presence of two missiles in the left thoracic cavity. One missile lay in the left midhilar region and the other in the anterior mediastinum, immediately overlying the left pulmonary hilus. The patient's condition remained critical in spite of resuscitative measures. The left lung showed no signs of re-expanding, and the pneumothorax persisted in spite of continuous decompression. Vigorous bubbling in the water seal continued until his death, forty-eight hours after entrance to the hospital. Unfortunately, this patient was treated during the battle for the Salerno beach-head and because of the tactical situation and the press of casualties, a post-mortem examination was not performed.

It is believed that this case presents an unusual set of circumstances in that the patient survived to reach the hospital, which at that time was in the active area of hostilities, and that the tension pneumothorax did not develop until late. One suspects that a blood clot or the missile itself acted as a plug to seal the bronchial wound, and that the manipulation involved in moving the patient for radiographic examination dislodged the seal or caused it to be "blown out," thus releasing air into the pleural cavity.

In retrospect, a bronchial leak should have been suspected when it became evident that the flow of air escaping from the pleural cavity through the water seal showed no signs of lessening after the first twenty-four hours. A thoracotomy with an attempt to close the bronchial wound should have been done at this time when it was evident that spontaneous sealing was not to be expected. His death may have been, in part, attributable to asphyxia due to loss of air from the bronchus.

(5) *Continuing Intrapleural Hemorrhage.*—Continued intrapleural hemorrhage requiring an exploratory thoracotomy for the control of bleeding was a rare occurrence. Indeed, we have encountered no case with a penetrating or perforating wound in which it was necessary to resort to an exploration for this indication.

The source of blood in the pleural cavity in the cases which arrived at the hospital was from the lung or from the vessels of the thoracic cage (internal mammary and intercostal vessels). Injuries of the large systemic and large pulmonary hilar vessels were not seen.

Bleeding from the lung readily controls itself by two mechanisms: (1) the formation of an intrapulmonary hematoma, and (2) atelectasis. The hematoma that results from infiltration of the pulmonary tissue surrounding a wound exerts a compressive effect upon the severed vessels sufficient to control bleeding. Atelectasis, which follows the escape of air from the pulmonary wound, may also exert a hemostatic effect because the elastic properties of the pulmonary tissue now constrict the lung into a more compact and solidlike organ.

The following observations, however, lead us to believe that the effective mechanism for the control of bleeding from the lung is the formation of the intrapulmonary hematoma. Atelectasis, when present, may play a small role, but only immediately after the injury.

(1) There were sixty-one patients with acute penetrating or perforating wounds of the chest upon whom thoracotomies were performed. The operation was done within an average of 15.2 hours following the wounding. (Thoracotomies were done on 4 additional patients, but for wounds more than forty-eight hours old, viz.: Cases 4 and 6). In each of the sixty-one cases there was encountered a turgid hematoma in the lung which surrounded the pulmonary wound for a distance of 2 to 5 inches. No active bleeding was seen to come from these hematomatous sites, although slight oozing was frequently observed. No measures to control bleeding were ever necessary, except in six instances in which active pulmonary hemorrhage occurred upon the removal of a large foreign body from the lung. *No bleeding from a hematoma followed complete expansion of the lung by positive pressure at the conclusion of the operation.*

(2) There were 181 cases of hemothorax as a result of a penetrating or a perforating wound of the chest in which thoracic exploration was not required. These were managed by debridement of the wound of the thoracic wall and by aspiration or by catheter drainage of the pleural contents. Of this group:

There were 153 cases in which the pleural cavity was treated by early thoracentesis. The initial thoracentesis was performed soon after the patient arrived at the hospital, an average of 12.2 hours after the injury was received. An attempt was made in each case to withdraw 500 to 600 c.c. of blood at this time. This was followed by daily thoracentesis without air replacement. The average period of time required for complete lung re-expansion, from the time of the first thoracentesis, was 5.7 days, and in no case was there a continuation of intrapleural bleeding.

There were twenty-eight cases in which the pleural cavity was treated by catheter drainage. Complete and sudden emptying of the pleural cavity of blood and air with resultant immediate expansion of the lung was effected in each case by the insertion of an intercostal catheter, or by catheter suction of the pleural cavity through the wound aperture. This was done on an average of 11.1 hours after the injury was sustained. The shortest time interval between wounding and emptying the pleural cavity of blood was 4.5 hours. In no case was there a recurrence of intrapleural bleeding that required surgical interference.

It is believed, therefore, that following a penetrating or perforating wound of the chest, continued bleeding from the lung into the pleural cavity is arrested by the formation of an intrapulmonary hematoma. The compressive effect of the hematoma prevents hemorrhage from severed pulmonary vessels. In the presence of a pneumothorax, the contractile elasticity of the atelectatic lung may also contribute to the control of early bleeding, but only to a minimal degree. Rapid expansion of the lung by emptying the pleural cavity of blood and air may therefore be undertaken early without the hazard of inciting hem-

orrhage. It should be undertaken early because the presence of air and blood in the pleural cavity serves only as a medium for infection and the development of an empyema.

Bleeding into the thoracic cavity may also arise from the internal mammary and intercostal vessels. It commonly has been stated that these vessels, when severed, are the usual sources for *continued* bleeding into the pleural cavity because of: (1) their relatively high (systemic) blood pressure and (2) the negative pressure within the thorax. We frequently have seen lacerated intercostal and internal mammary vessels during the course of a debridement, or during a thoracotomy. In some instances they have been completely transected. In all cases, however, hemostasis was self-effected by thrombosis and retraction of their severed ends. When hemorrhage was encountered, it was due to the disturbance caused by surgical manipulations, or incidental to the removal of a foreign body tightly lodged within an intercostal space. It was always possible to control bleeding without resorting to thoracotomy either by directly clamping the bleeding point, or by encircling the vessel with a suture in the intercostal space, proximal to the area of damage. Although the internal mammary and the intercostal vessels, when injured by shell fragments, will contribute to the formation of a hemothorax, there has been no case in which a thoracotomy was required for the control of continued intrapleural bleeding from these vessels.

The aforementioned mechanisms, however, may foster continued bleeding when the parietal vessels are severed by sharp objects, as, for example, by knife blades or by the serrated edges of fractured ribs. But it is our belief that when their continuity is disrupted by the passage of a shell fragment, other factors are brought into play which engender hemostasis. These are: (1) the coagulation of tissue and the sealing of blood vessels by the hot shell fragment, (2) the thromboplastic effect of contused muscle and endothelial tissue.

There was only one instance in which it was necessary to explore the thorax for the control of continued intrapleural bleeding. This was the result of a crushing injury of the left thorax. Upon exploration, the supreme intercostal vein was found lacerated by the sharp edge of a fractured rib.

Summary of cases that required thoracotomy: There were sixty-five cases with penetrating or perforating wounds of the chest upon whom thoracotomy was performed. Many of these, thirty-five in number, required, in addition, exploration of the peritoneal cavity through the diaphragm. The following table classifies the cases according to the indication for which thoracotomy was done:

TABLE I

INDICATIONS FOR THORACOTOMY	CASES TREATED BY THORACOTOMY
The anatomic likelihood of diaphragmatic penetration	44
The presence of large intrapulmonary and intrapleural foreign bodies	16
The presence of missiles in, or traversing the mediastinum	5
Wounds of the large bronchi*	0
Continuing intrapleural hemorrhage*	0
Total	65

*See discussion of this topic.

It is interesting to note that the greatest number of thoracotomies, forty-four, or 67.7 per cent, were done because a diaphragmatic penetration was suspected. Of this group, nine explorations were negative so far as finding a diaphragmatic wound was concerned, but they were undertaken because the presence of such a lesion could not be excluded without direct visualization.

There were, therefore, thirty-five patients who had thoracoabdominal explorations, and 30 patients who had only thoracic explorations for wounds limited to the pleural cavity and its contents. There were five deaths, a total operative mortality of 7.7 per cent.

In the thoracoabdominal group there were two fatalities, a mortality of 5.7 per cent. Both occurred in cases in which the right diaphragm was involved.

In the group with wounds limited to the pleural cavity and its contents, there were three deaths, a mortality of 10 per cent. These occurred in those patients in whom there existed a "traumatic thoracotomy."

Of the five patients who did not survive: one died of shock while on the operating table; two died of uremia on the sixth postoperative day, and two deaths were due to bronchopneumonia. The death of one patient with bronchopneumonia was partly due to the presence of a high thoracic spinal cord injury with paralysis of the intercostal and abdominal musculature. The two patients who expired from uremia were in profound shock upon admission to the hospital. It was only after prolonged resuscitative treatment that they were brought into suitable condition to undergo operative treatment. The spectre of the "shocked kidney" with its threat of anuria constantly hovers over the patient who remains in the state of clinical shock for prolonged periods.

II. WOUNDS THAT DO NOT REQUIRE THORACOTOMY

Wounds that entered the thoracic cavity but in which there existed no indication for thoracotomy comprised the greatest proportion of cases. Thus, out of 285 patients, 220, or 77.1 per cent, did not require exploration. The general management of such wounds consisted of: debridement, the prevention of sucking by suturing the breach in the thoracic wall, and the evacuation of blood and air from the pleural cavity to obtain early expansion of the lung. The technique of treatment varied and was dependent upon the severity of the injury. For this reason, wounds of this group were classified according to the extent of damage that had been inflicted: (a) wounds of the thoracic cavity uncomplicated by the existence of a hemothorax and/or pneumothorax; (b) wounds of the thoracic cavity complicated by the existence of a hemothorax and/or pneumothorax; and (c) sucking wounds.

(a) The pleural cavity may not contain a hemothorax or a pneumothorax following a thoracic wound because of the mildness of the injury or because of obliteration of this space by previous disease. Small, smooth missiles sometimes produce so little damage to the inner wall of the chest or the lung parenchyma that little or no blood and air escape to accumulate within the pleural cavity. These cases required only debridement of the wound of the thoracic wall. It is important, however, not to overlook the tardy appearance of an effusion which

may collect one to three days postoperatively. The original roentgen films may show no such complication.

Obliteration of the pleural cavity by fusion of its visceral and parietal surfaces due to an old pleuritis may prevent the lung from collapsing, and thus prevent the intrapleural collection of blood and air. But blood and air may escape from the lung directly into the wound and the soft tissues of the thoracic wall. Marked degrees of subcutaneous emphysema were seen in a few such instances. Treatment consisted of debridement and occlusion of the wound by suturing the contiguous muscle over the aperture in the thoracic cage. A compression dressing was then applied to discourage the further escape of air into the tissues.

(b) Patients whose wounds were complicated by the presence of a hemothorax and/or pneumothorax, required, in addition to debridement of the soft tissue wounds, treatment of the pleural cavity. This consisted of aspiration of the pleural contents and sometimes the use of an intercostal catheter with water-seal drainage. A determined effort was made to evacuate the pleural cavity of blood and air as rapidly as possible during the early postoperative period. A prolonged delay in re-expansion of the lung invites the occurrence of serious sequelae, as organizing hemothorax, empyema, chronic atelectasis, and fibrothorax.

A hemothorax was rarely found alone. Usually blood and air coexisted and the radiologic film showed a fluid level. Aspirations were commenced early. The initial one was performed in the preoperative ward, or in the operating tent before anesthesia was induced, and 500 to 600 c.c. of blood were withdrawn at this time. Dyspneic patients with large hemothoraces sometimes required more than one aspiration before debridement of the wound was attempted. Recurring dyspnea relieved by thoracentesis should alert one to the possibility of continuing hemorrhage into the pleural cavity. A careful record of the amount of blood obtained by each aspiration served not only as a means of ascertaining the occurrence of hemorrhage, but as a rough index to the amount of blood replacement that was necessary.

Following the initial thoracentesis and debridement, aspiration of the pleural cavity was resumed daily on the postoperative ward. Blood was withdrawn in amounts up to 700 to 800 c.c. per thoracentesis, or until the patient complained of a sense of tightness within the chest. Replacement with air was not done, except as a palliative measure to relieve the discomfort which sometimes followed thoracentesis. When necessary, 40 to 80 c.c. of air injected into the pleural cavity sufficed to relieve the distress. With this regime most patients completely re-expanded their lungs in from four to six days and were then evacuated to the base.

Pneumothorax, while usually in association with a hemothorax, was sometimes seen alone or as a predominant feature. A minimal degree of pneumothorax was not treated. One of moderate size was treated by daily aspiration of air. It was found, however, that a large pneumothorax was best managed by rapid and complete evacuation. This was done at the operating table. Immediately following debridement, a needle was inserted into the pleural cavity

and positive pressure anesthesia, applied for a few minutes, forcibly expelled the air from the pleural cavity.

Tension pneumothorax was a complication not commonly seen in an evacuation hospital. In the present series of 285 wounds of the chest there were six patients with tension pneumothorax. These developed spontaneously, incidental to moving the patient from the litter to the cot, on the operating table during the course of debridement, or following thoracentesis. There were no cases which presented this condition upon admission to the hospital.

(c) Small sucking wounds were managed by debridement, by the approximation of soft tissue over the sucking site, and by emptying the pleural cavity of its contents. Wounds of this nature frequently revealed themselves only during the course of debridement. The heavily muscled portions of the chest were the common areas where such concealed wounds were encountered. After the excision of damaged tissue, one or two layers of muscle were sutured over the breach in the thoracic cage. The skin was left open. In the thinly muscled areas, however, it was sometimes necessary to suture the skin, in addition, to prevent sucking.

With larger sucking wounds, those, for example, admitting one or more fingers into the chest, the pleural cavity was evacuated before closure was begun by the introduction of an aspirating catheter through the wound aperture. A warm solution of physiological sodium chloride was used when necessary for irrigation, to extract the blood clots. Where the intrathoracic damage was great, and where difficulty was encountered in evacuating the pleural cavity of blood clots, an intercostal tube was inserted. Evacuation of the pleural contents could be achieved by through-and-through irrigation, using the wound as the point of injection and the tube as a point of exit for the irrigating solution. Upon completion of the toilet of the pleural cavity, the lung was expanded by positive pressure before the wound was closed. The intercostal tube was left for the purpose of providing closed drainage. The reaccumulation of pleural fluid demanding thoracentesis occurred but rarely when a closed system of drainage was kept patent and functioning for forty-eight hours.

Sucking wounds of such large size as to allow the introduction of a hand into the pleural cavity have been discussed above. Although reconstruction of the thoracic wall constituted the major part of the operative procedure, the manual removal from the pleural cavity of indriven segments of chest wall and foreign material was also done. This group of cases, therefore, was considered among those in which thoracotomy was done for the removal of intrathoracic foreign bodies.

Summary of patients who did not require thoracotomy: There were 220 patients with penetrating or perforating wounds of the chest that did not require thoracotomy. There were ten deaths, a mortality of 4.5 per cent. Of these, five had associated injuries of the thoracic spinal cord, three died of complications resulting from associated intra-abdominal wounds, one died of asphyxia due to bronchial injury (see "bronchial injuries"), and one death was caused by idiosyncrasy to pontocaine. It had been applied topically as a preliminary to bronchoscopy. Paralysis of the intercostal and abdominal muscles

consequent to spinal cord injury makes the patient unable to expel blood and secretions from the air passage. In the five cases noted above, death resulted from unavoidable pulmonary edema or bronchopneumonia.

PREOPERATIVE AND POSTOPERATIVE CARE

Preoperative and postoperative care was directed toward the achievement of three basic aims, namely, the restoration of respiratory equilibrium, the restoration of circulatory equilibrium, and the prevention of infection.

Respiratory distress was corrected by measures directed toward the accomplishment of two main purposes: (1) the maintenance of a clear tracheobronchial tree, and (2) expansion of the lung.

The tracheobronchial tree was generally cleared of blood and secretions in the responsive patient by his own efforts, particularly if the pain on coughing was allayed by anesthetization of the intercostal nerves. Nerve block by the injection of procaine solution along the course of multiple intercostal nerves on the injured side was a procedure which was used with great frequency. Indeed, this was almost routine before operation and during the postoperative period. With wounds that lay close to the spinal column, it was necessary to inject the solution close to the intervertebral foramina. Adequate anesthesia was obtained by using 5 c.c. of a 2 per cent solution of procaine hydrochloride in each intercostal space. Coughing was also encouraged by the establishment of a cough routine. A ward attendant was trained to hold the patient's chest while urging him to cough. This procedure was carried out for ten minutes each hour. The semiconscious or the unconscious patient who was unable to clear his air passages was aided by the intratracheal introduction of a suction catheter or by bedside bronchoscopy. Thoracic casualties with associated spinal-cord injuries at thoracic levels demanded frequent bronchoscopic aspirations before and during the postoperative period. The cough in such cases was ineffectual because of intercostal and abdominal paralysis; the higher the paralytic level the more ineffective the cough.

Expansion of the lung by thoracentesis, with resultant increase in the vital capacity, was begun in the preoperative tent. Blood (and air) in the amount of 500 to 600 c.c. was usually aspirated at this time. It was sometimes necessary to perform more than one thoracentesis before operation. In several instances, because of alarming respiratory embarrassment which was not due to tension pneumothorax, an intercostal tube was inserted into the pleural cavity with resulting rapid expansion of the lung following the complete evacuation of pleural blood into a waterseal. Following operation, thoracentesis was performed daily in order to expand the lung as quickly as possible. Blood obtained by aspiration was sometimes returned to the patient as an autotransfusion, but this was not done when more than twenty-four to thirty-six hours had elapsed from the time of injury because of the possibility of bacterial growth and hemolysis of the red blood corpuscles.

The use of oxygen as an adjunct in the treatment of respiratory distress was routine and requires no further comment.

Circulatory imbalance was treated by the administration of citrated whole blood. The casualty with a thoracic wound was usually in need of whole blood,

not only because of external loss, but due to intrapleural accumulation. Plasma, while an excellent means for bolstering the circulation, is at best but a temporary substitute for blood. Its value is undisputed for emergency use in the battalion aid station where blood was not available. In the hospital, however, a ready supply of low titer, citrated, Type IV whole blood was available at all times. While cross matching was routine, we did not hesitate to administer Type IV low titer whole blood in emergencies without this preliminary precaution. The incidence of "transfusion reactions" following this procedure was no greater than that where cross matching preceded the transfusion.

There is no given standard for the quantity of blood to be given to the wounded patient. Blood was given in an amount sufficient to bring about an adequate and stabilized response. It was not unusual for this to require as much as 1,000 to 1,500 c.c. of blood. Movement of the patient for roentgenographic study or to the operating tent was not undertaken until circulatory equilibrium had been restored. This did not mean that a normal pulse rate and blood pressure were obtained. Movement was undertaken when it was believed that these vital functions had reached the best possible level that could be attained and maintained.

The factor of greatest importance in the prevention of infection during the postoperative period was the early obliteration of the pleural space by an expanded lung. The necessity for achieving this condition by repeated daily thoracentesis has already been emphasized. Penicillin was given intramuscularly in the amount of 25,000 units every three hours. This was begun at the time of the patient's entrance to the hospital and was continued until the lung was completely re-expanded.

SUMMARY

The experience with 285 penetrating and perforating wounds of the thorax treated at a 750-bed evacuation hospital during the Italian Campaign is presented.

Wounds of the chest are divided into two groups:

I. Those which require thoracotomy
II. Those which do not require thoracotomy

Group I: There were sixty-five patients whose wounds demanded thoracotomy. This includes thirty-five patients with thoracoabdominal wounds in which the peritoneal cavity was explored, in addition, by means of a transdiaphragmatic approach.

There were five deaths, a mortality of 7.7 per cent. Three occurred in the group of thirty cases in which the wound was limited to the thoracic cavity and its contents, a mortality of 10 per cent. Two occurred in the thoracoabdominal group, a mortality of 5.7 per cent. In both latter fatalities the wound involved the right diaphragm.

The indications for thoracotomy are discussed.

Group II: There were 220 cases whose wounds did not require thoracotomy. There were ten deaths, a mortality of 4.5 per cent.

The management of the cases comprising this group is presented. A consideration of preoperative and postoperative care is included.

TRAUMATIC RUPTURE OF THE BRONCHUS

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TRAUMATIC rupture of the bronchus occurs very rarely, and is recognized clinically with even greater infrequency. Occurring as it does with severe trauma to the chest usually of a compression or crushing type, it passes unrecognized because of the unfamiliarity with the condition and because the patient is usually in such a serious condition that adequate studies for its recognition cannot be or are not made.

From the literature over the years, at least 38 cases of rupture of the bronchus have been reported. A great many of these have been fatal immediately or within a relatively short time following the accident, and were usually unrecognized as bronchial rupture until post-mortem examination revealed the true condition. A smaller number of patients have slowly recovered spontaneously with the exact nature of the condition unrecognized for months or even years following the injury. A few patients' conditions have been correctly diagnosed early and they have survived the accident.

The history in most cases is very much the same. A young individual (the age range has been from 3 to 74 years), usually a male, sustained a severe chest injury of a compression or crushing type, most usually by the passing of a car or truck or wagon wheel over the chest, and less commonly by a squeeze, a direct blow, or a fall. The ribs may or may not be fractured. Hemoptysis may or may not occur. Shock is usually profound. Marked dyspnea and cyanosis may follow if a tension pneumothorax develops. An extensive hemothorax may or may not occur. Subcutaneous emphysema may occur, but is often not a prominent part of the picture. Death may occur promptly if one of the large vessels in the hilum is torn at the same time, and more slowly if a smaller vessel is torn or a marked tension pneumothorax develops unrecognized. The patients who recover spontaneously usually do so after a rather stormy convalescence and are subsequently found to have an atelectatic functionless lung on the affected side.

The exact mechanism by which this lesion occurs is not always quite clear. It has invariably been associated with a crushing injury of the chest, with or without accompanying rib fracture. That the rupture is not the result of penetration of a rib fragment is quite evident by the occurrence of the condition without demonstrable rib fracture, or with fractures in such a position that a fragment could not possibly make contact with the bronchus at the site of laceration. From the results produced, it seems quite evident that a severe shearing force must have been brought to bear upon the bronchus, bringing about its rupture. The point most likely to tear appears to be the main bronchus at or within a few centimeters of the trachea, although in one of the cases here reported there

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was not only a rupture of the right main bronchus about 2.5 cm. from the carina but also a rupture in the upper lobe bronchus on the same side.

Both right and left sides have been involved with approximately equal frequency. Rupture of the lung parenchyma has not been a common association with this injury, although one might expect the more delicate lung tissue to be split or torn more readily than the firmer, more rigid bronchus. Strangely enough, the arteries and veins of the pulmonary hilum have not sustained injury from the same force in the majority of instances, although the thinner wall and fluid content would theoretically seem to make them more susceptible to rupture. Following the bronchial tear, a pneumothorax of varying extent frequently develops (sixteen out of thirty-eight) which may or may not progress to the tension pneumothorax stage. Emphysema may be slight if peripheral and associated with rib fractures only, but may be extensive and even alarming and dangerous if it results from bronchial rupture within the mediastinal pleura. It has been mentioned in only twelve of the collected cases and since eight of these recovered, its prognostic import is not too serious.

Bleeding in varying amounts into the pleural cavity frequently follows (ten out of thirty-eight) depending on the size and type of blood vessels which are injured. It may at times be extreme or even exsanguinating. (Seven have died and three recovered in this group.) A varying amount of bleeding into the lumen of the bronchus likewise occurs. (Nine of thirty-eight cases with five deaths.) This blood may be a contributing factor in the production of atelectasis in the involved lung, and the clot in the bronchus may act as a scaffolding over which bronchial mucosa may develop to produce a membrane such as is described in the case reported by Piaget,[27] and in Case 1 of this report. Complete or nearly complete bronchial occlusion occurs if the patient survives with the development of a marked atelectasis of the involved lung, followed by an extremely marked shift of the heart and mediastinum toward the affected side, producing the dyspnea, chest discomfort, and other symptoms, of which some of these patients subsequently complain. If the obstruction is not complete, secondary bronchiectasis and inflammatory changes are likely to ensue.

The authors have abstracted the following thirty-eight cases collected from the literature, and wish to add two of their own, hitherto unreported, both with recovery:

HISTORICAL

Winslow, 1871:[1] "Rupture of bronchus of wild canvasback duck." Rupture of left main bronchus on outer side where it joined trachea, healed with formation of thin, fibrous pouch about it.

Seuvre, 1873:[2] Woman aged 74, struck by omnibus; wheel passed over chest; unconscious; hemoptysis; emphysema; died on admission. Fracture right elbow; fracture right first, second, and third and left first and second ribs; mediastinal hematoma; laceration of vena cava; right bronchus completely separated from trachea; split posterior wall trachea.

Gross, 1885:[3] Man 21 years old. Wheel of coal cart ran over anterior upper chest. Fracture of maxilla; dislocation of outer and inner end left clavicle; left I costochondral separation; fracture right third and fourth ribs; profuse hemoptysis; left pneumothorax; left empyema. Died four days. Almost complete rupture of left bronchus, one centimeter before it entered lung.

Lannelongue, Odilon:[4] Case of bronchial rupture quoted by Gross. Reference not verified.

Sheild, A. Marmaduke, 1889:[5] Man aged 47, crushed between van pole and wall, died instantly. Fracture of right anterior ribs, sternum, and left third and fourth ribs posteriorly. Rib ends penetrated mediastinum. Complete rupture of left bronchus at junction with trachea; much blood in mediastinum; pericardium torn; lungs bruised—not torn; heart, great vessels, esophagus, and nerves uninjured.

Specimen, Middlesex Hospital: Rupture of main bronchus, quoted by Sheild.

Specimen, St. George Hospital: Rupture of secondary bronchi, quoted by Sheild.

Rolleston (Nov. 4, 1890), 1891:[6] Man 60 years old, run over by express train and killed instantly. Multiple spine fractures; spinal cord cut; fractures of all ribs on both sides; two ruptures of right ventricle; aorta severed in two places; liver ruptured; right lung complete detached; left bronchus cut across close to trachea.

Rolleston (Fig. 17, 1891), 1891:[7] Soldier run over by road car. Fracture right ribs one to five, two to nine ribs, and dorsal spine. Complete rupture of right bronchus just below bifurcation. Posterior rupture extended into trachea. Pulmonary artery and veins severed. Died instantly.

Barford, J. Leslie, 1906:[8] Four-year-old boy, run over by half-loaded van. Hemoptysis, dyspnea, intermittent cyanosis, emphysema, neck and face. Died forty-five minutes after accident. Post mortem showed fractures left ribs five, six, and seven at spine. No pneumothorax. Left bronchus completely detached from trachea at bifurcation and torn down posterior wall. Trachea split up posterior wall for one inch.

King, 1907:[9] Girl 4 years old, knocked down by rubber-tired brougham. Fractured left ribs five to eight. Right tension pneumothorax; coughed up blood. Catheter inserted for under-water drainage. Died in fifty-five hours, rupture of right main bronchus. Hilar vessels intact.

Moty, 1907:[10] Soldier. Caisson wheel over chest. Multiple rib fractures; emphysema, generalized; bloody, frothy sputum. Died soon. No pneumothorax. Separation of both bronchi from trachea. Heart and large vessels not injured.

May, W. Norman, and Bowen, W. H., 1907:[11] Boy 15 years old, fell from bicycle. Wheels of van passed over head. Bilateral skull fractures; operated. Unconscious, dyspnea, cyanosis, right pneumothorax (decompressed). Died in twenty-six hours. Post mortem: right pneumothorax, right main bronchus torn completely across just below bifurcation, ends separated ½ inch; ribs, clavicle, pleura, and hilar vessels uninjured.

Tiegel, 1911:[13] Six-year-old boy. Wagon wheel over chest and abdomen. No rib fractures; left tension pneumothorax; died eight hours. Complete tear through left main bronchus; great vessels not injured; no lung injury; no hemothorax.

Schonberg, 1908:[12] Man 20 years old, crushed between two iron buffers and killed. Transverse severance of trachea.

Schonberg, 1912:[14] Case 1. Boy 3 years old, run over by heavily loaded wagon. Severe dyspnea, marked emphysema, left tension pneumothorax—decompressed by needle and open drain tube. Died five hours. Complete tear left main bronchus, fracture right thigh, no rib fractures. Fat emboli. Case 2. Man 25 years of age, crushed by loaded coal wagon tipping over on him. Fracture right fifth rib. Severe hemoptysis; right hemopneumothorax; fat emboli; avulsion right main bronchus; laceration of right upper lobe. Died soon. Case 3. Girl of 12 years, run over by wagon. Died soon. Avulsion of left main bronchus; large pulmonary tear left upper and lower lobes; left hemopneumothorax; left pulmonary atelectasis; fat emboli.

Mumford, W. G., and Leckie, A. J. Bruce, 1912:[15] Boy 9 years old. One wheel of motor passed over chest. No rib fractures. Marked emphysema. Died eight hours. Right pneumothorax; right bronchus torn at junction with trachea attached only by connective tissue.

Patrick, 1917:[16] Thirty-four-year-old soldier. Wheel of empty limber passed over chest. Orthopnea, emphysema; fracture left ribs three to seven and sternum; left hemothorax. Died seventy-two hours. Left bronchus torn from trachea through anterior two-thirds of circumference. Acute pericarditis.

Leveuf and Monod, 1919:[17] Man aged 56, buried by block of dirt in ditch. Emphysema; marked, asphyxia. Died in few hours as chloroform anesthesia started. Autopsy: transverse

fracture right stem bronchus at union of upper two-thirds and lower one-third. Comminuted fractures upper eight ribs on right, and upper nine on left. No free blood.

Thomas, Lillienthal, 1926:[18] Twenty-two-year-old man crushed beneath overturned coal wagon. No rib fractures. Progressive emphysema. Died in nine and one-half hours. Right bronchus ruptured at bifurcation; massive mediastinal hemorrhage; right hemothorax.

Krinitzki, 1928:[19] Woman aged 31, injured at age of 10, when keg of wine 80 kg. fell on chest. Fracture four ribs right; severe illness for two months; slow recovery. One year later, right exudative pleurisy. Five years later, pleurisy again. Pulmonary tuberculosis for seven years. Died. Complete obstruction right main bronchus 3 cm. from trachea. No tuberculosis in right lung.

Meade and Graham, 1930:[20] Negro man 19 years old, crushed between truck fender and road bank. Cyanosis, dyspnea, shock, subcutaneous emphysema, left pneumothorax. Died sixteen hours. Complete rupture right main bronchus 5 cm. from bifurcation; no rib fractures; no right pneumothorax.

Jacchia, Paul, 1931:[21] Man aged 42. Laborer. Admitted Sept. 17, 1930. Injured August, 1917. Horses ran away, thrown under wheels. Fractures of left second and third ribs. Some hemorrhage and fever. Slow recovery. Much discomfort in left lower thorax for months. Returned to work. X-ray, 1930, left atelectasis.

Supino, 1935:[22] Man 43. Injury at 10. Struck by vehicle, fractured nine ribs. Old rupture right main bronchus, occlusive cicatricial stenosis with permanent collapse of the right lung and contralateral vicious pulmonary hypertrophy. Autopsy.

Nicod and Urech, 1936:[23] Jockey fell from horse. No fractures. Emphysema, dyspnea, left hemopneumothorax aspirated. Recovered two weeks. Left lung did not expand. Died ten years later, ruptured esophageal varix. Left pleural cavity free; no adhesions. Left main bronchus occluded 5 cm. below bifurcation. Old fracture displaced and scarred. Distal bronchi filled with mucus.

de Gaulejac and DeMarez, 1936:[24] Young soldier. Severe injury at 9 years of age. Multiple rib fractures. Right pleuropulmonary injury. Right hemothorax, infected. In bed, hospital, for six months. Home one year. Acquired dextrocardia. No symptoms, no bronchoscopy or bronchograms. Not a proved case of bronchial rupture, but probable.

Rienhoff, 1936[25] Case 1. Three and one-half years old. Traumatic rupture left main bronchus; recovered. Living thirty-two years later in good health. Case 2. Nine years old. Traumatic rupture left main bronchus; recovered. Living twenty years later in good health.

Jones, Frank W., and Vinson, Porter P., 1939:[26] Woman 22 years old. Auto accident. Fracture right first rib. Dyspnea, cyanosis, emphysema, bilateral pneumothorax; repeated aspiration and cannula inserted; suprasternal incision for mediastinal emphysema; recovered; atelectasis (left) from stenosis of main bronchus.

Piaget, 1939:[27] Boy 4 years old had crushing injury. Dyspnea, edema of neck and upper chest, right tension pneumothorax decompressed by continuous aspiration. No rib fractures. Right pleural effusion, purulent, drained. Recovered. Discharged two months. Total right atelectasis. Bronchoscopy showed diaphragm with small opening 3 cm. from bifurcation. Bronchogram showed block of right main bronchus with bronchomediastinal fistula. Diaphragm perforated through bronchoscope and lung aerated. Large fibrothorax and dextrocardia.

Specimen: Guy's Hospital Museum No. 178. Man aged 51. Left bronchus ruptured at bifurcation just within lung. Quoted by Piaget.

Piquet, Muller, and Marchand, 1939:[28] Man aged 31. Crushed against wall by machine. Thorax compressed. Double fracture maxilla, and fractures of third and fourth left ribs. Bloody sputum, forty-eight hours; cough on swallowing liquids. Ingested barium entered right lower bronchus. Traumatic fistula esophagus to right main bronchus.

Clerf, 1940:[29] Man aged 31. Auto accident four months previously. Dyspnea, cyanosis, emphysema. Fracture left first rib and arm. Total left atelectasis. Left bronchus obstructed 4 cm. from carina. Left pneumothorax initial reading (16 cm. of water) 2,000 c.c. of air injected relieved dyspnea and chest oppression.

Clerf: Boy aged 9, injured in auto accident at age of 4 with fracture of five ribs and injury to right lung. Recovered. Complete atelectasis; right main bronchus obstructed 1 cm.

from carina; all right thirteen years after accident except for flattening of right chest and slight secondary scoliosis.

Bauer, 1940:[30] Man aged 48. Accident at age of 16. Two fractured ribs. Thoracentesis. Recovered. Heart displaced into right chest. Soldier 1914-18. Metal grinder. Bronchial catarrh; pneumonia at 48. Died five days, pulmonary embolism. Autopsy: right main bronchus completely obstructed 1 cm. below bifurcation; bronchi filled with glairy mucus.

Loffler and Nager, 1941:[31] Woman aged 31. Injured Sept. 9, 1939, in automobile accident. Chest crushed between motor and back of seat. Fracture of clavicle, right first and second ribs, and probable fracture of sternum; right hemopneumothorax. In hospital three and a half months. Stenosis of right main bronchus 2 cm. below bifurcation, and also another in cardiac branch; atelectasis right; two attacks of bronchopneumonia; repeated bronchial dilatation and coagulation (90 treatments) over fifteen months. Improved. Ambulatory. Vital capacity under 1,500 c.c.

Tyson and Lyle, 1942:[32] Male aged 26. Auto accident four months before. Unconscious, cyanotic, fracture of left scapula; coughed up bright red blood. Discharged one month. Examined three months later, chest pain and dyspnea, marked displacement of mediastinum to left. Vital capacity 54 per cent. Left bronchial obstruction 3 cm. from trachea; biopsy normal. Left intrapleural pressure -38 cm. of water; later, -58, -44. Pneumothorax treatment and relief of pain.

PERSONAL CASES

CASE 1.—H. D., male, aged 15, was first seen in consultation on Dec. 6, 1943, referred by Dr. G. R. Waldren of Cavalier, N. D., because of dyspnea, cough, and expectoration. His family history was negative while the past history revealed diphtheria at the age of 10, pneumonia at the age of 11, and a bilateral herniorrhaphy and appendectomy at the age of 10. His general condition had been good until August, 1941, when the front wheel of a farm truck was driven partially onto his right chest from above, fracturing his right clavicle and first rib, but inflicting no other known injury. Immediately he began to expectorate blood which continued in rather large amounts for the next twelve hours. He had moderate pain for a few hours, coughed a great deal, but did not develop emphysema. He was taken to his home and placed in bed. A doctor from the adjacent town was called. His chest was taped tightly, he was given some pain pills, sulfa drugs, and a transfusion, but no other therapy. Three weeks after his injury, physical examination of his chest revealed a large accumulation of fluid in the right pleural cavity. This was tapped and about one-half cup of rather thin, bloody fluid was removed. There had been no subsequent aspiration.

He remained in bed for one month without fever and was then up and about for two months. He was then examined by another physician, thought to have tuberculosis, and was sent to the North Dakota State Sanatorium, where a brief study confirmed the impression that his condition was not tuberculous. He was then transferred to the Trinity Hospital in Minot, North Dakota, where additional x-rays were taken and bronchoscopy carried out. This revealed a complete occlusion of his right main bronchus which could not be opened. Iodized oil was injected and bronchograms made. He was returned to his home for two weeks and then returned for additional examination, was bronchoscoped again, and again the bronchus could not be opened. A right pneumonectomy was recommended.

Since that time he had remained at home, never acutely ill but troubled by frequent cough, raising of one to two ounces of sputum a day, foul at times, particularly in the morning, but without wheezing or hemoptysis. He had occasional bouts of low-grade fever and was continuously short of breath, particularly on exertion. He has always suffered from sinus disease and frequent colds, at least six or seven per year, most of which migrated to the chest and hung on for two or more weeks. He was able to carry on some of his farm chores but tired rapidly and became short of breath on exertion.

Physical examination revealed a thin, rather well-developed boy, 5 feet 6 inches tall, weighing 125 pounds. His blood pressure was 110/58, temperature 98.4° F., pulse 86, and respiration 22. Strong cardiac pulsations were visible through the right chest wall. The tones were clear, regular, and without murmurs. There was marked deviation of the trachea to the right, with a flat percussion note throughout the right side, with breath sounds absent except in the parasternal region. The left side of the chest shows a normal percussion note

throughout with absence of the normal cardiac dullness. Breath sounds were heard throughout with no râles present. The extremities were negative with no clubbing of the digits or watch-crystal nail changes.

The hemoglobin was 100 per cent, erythrocytes 5,490,000, leucocytes 9,600, polymorphonuclears 76 per cent, lymphocytes 21 per cent and eosinophiles 3 per cent. The coagulation time was 2 minutes, 30 seconds, bleeding time 2 minutes. The sputum examination revealed a slightly purulent sputum without odor with no tubercle bacilli but numerous secondary organisms present.

X-ray examination of the chest showed a marked retraction of the heart and mediastinum into the right lung field and practically complete obliteration of the right lung. There was considerable peribronchial density in the left base with evidence of a deposit of iodized oil along the bronchial tree from previous lipiodol injection.

Bronchoscopic examination by Dr. A. C. Kerkhof was reported as follows: The bronchoscope was passed in the usual manner with no difficulty in getting into the first portion of the right main bronchus. In this area there was about 0.5 c.c. of very thick pus which was removed by suction and the bronchoscope inserted somewhat further. The right main bronchus then took a direction directly posterior, making it impossible to go farther into this pocket. There were no bronchial rings seen in this pocket. The mucosa seemed to be completely normal in appearance. No attempt was made to biopsy the mucosa. Iodized oil was instilled and bronchograms made.

Fluoroscopic examination was made during the instillation of iodochloral into the right main bronchus. The iodochloral was permitted to fill the right main bronchus and spill over into the lower bronchus on the left side.

From a study of these roentgenograms, Dr. Russell W. Morse stated that about 1.5 cm. below the carina there was a rather blunt obstruction of the right main bronchus. No iodochloral passed beyond this point. There was no bronchiectasis on the left side. The left lung showed compensatory increase in ventilation and extended about 5 cm. to the right of the medial line. The heart seemed to be retracted almost to the right lateral chest wall. There was apparently complete atelectasis of the right lung and either considerable pleural thickening or some free fluid in the right pleural cavity.

A right total pneumonectomy was recomended because of the bronchial obstruction, atelectasis, and infection which apparently was developing, and was performed on Feb. 19, 1944, under intratracheal cyclopropane anesthesia. Fibrous scar tissue in the right hilum made the dissection of the vessels difficult. The pulmonary artery and veins were smaller than normal by at least 50 per cent. The bronchus was surrounded by dense scar tissue which, however, did not seem to be producing the stricture. The bronchus in an area about 2.5 cm. from the bifurcation was collapsed and somewhat atrophic and was less than 1 cm. in diameter. There was no tumor mass to be felt through the bronchial wall. As the bronchus was already apparently completely obstructed, it was sectioned distal to the stenosis. The proximal bronchial stump was seen to be occluded by a crescent-shaped membrane which extended across the bronchial lumen, filling at least nine-tenths of the opening. It seemed to be soft, slightly bulged, and had the appearance of normal bronchial mucosa. At its upper border there was a small, incomplete opening through this mucous membrane with a small amount of mucopurulent secretion about it in the bronchial lumen distal to the stenosis. There were no enlarged lymph nodes in the hilar region.

The excised right lung showed extensive atelectasis throughout all lobes. Only a few small patches of air containing lung were present in the lower lobe. A catheter was tied into the main bronchus of the specimen, lipiodol injected and x-ray films made which revealed filling of only the middle and lower lobes. The upper lobe failed to fill because of complete obstruction of the upper lobe bronchus. There was no evidence of bronchiectasis. Microscopic sections showed only diffuse congestion with thickening. Dissection of the upper lobe showed an inflamed bronchus filled with pus ending in a blind pocket in the hilum of the lung. No communication could be demonstrated between the upper lobe bronchus and the branches to the lower lobe. Presumably there had been complete separation of the upper lobe bronchus from the intermediate bronchus with healing and complete occlusion. In this lung there had been not only a tear of the right main bronchus with healing and occlusion

PLATE I. H. D.

Fig. 1.

Fig. 2.

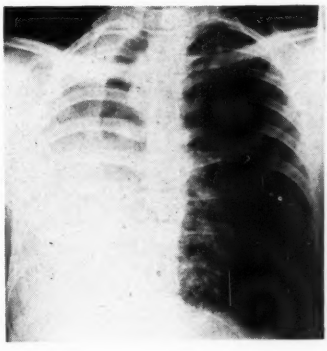

Fig. 3.

Fig. 4.

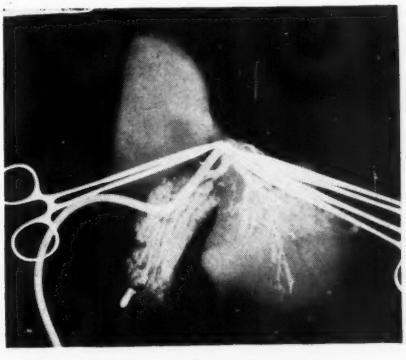

Fig. 5.

Fig. 1.—H. D. Sept. 13, 1941. X-ray film three weeks after injury. Fracture right first rib, right hemopneumothorax, atelectasis, right lung.

Fig. 2.—Sept. 27, 1941, atelectasis, right. Fluid in right pleural space. Air has absorbed.

Fig. 3.—Feb. 19, 1944, marked atelectasis, right lung. Marked displacement of heart and trachea to right. Occluded right main bronchus.

Fig. 4.—1944, bronchogram; total occlusion of right main bronchus.

Fig. 5.—Bronchogram of excised right lung showing occlusion of upper lobe bronchus.

by membrane formation about 2.5 cm. from the carina, but also a rupture of the right upper lobe bronchus with healing and complete obstruction.

The surgical procedure was well tolerated, the patient being given 500 c.c. of blood and 500 c.c. of normal saline on the table and an additional transfusion of 500 c.c. of citrated blood after his return to the room. The postoperative condition was good and convalescence quite smooth except for an accumulation of fluid under the pectoral muscles requiring several aspirations. The patient was discharged from the hospital ambulatory on the thirtieth postoperative day.

CASE 2.—R. B., a boy aged 7, on September 6, 1944, was crushed between the back of a truck and the wall of a brick building. Apparently his chest was squeezed in a lateral direction. He was able to run about 150 yards to his home where he collapsed. He was brought immediately to the hospital where he was examined by one of the authors (L. W. J.). On admission there was marked dyspnea and cyanosis. There was some bruising of the right side of his chest and of the left upper arm. There was marked subcutaneous emphysema over the suprasternal notch, extending over the chest anteriorly and posteriorly, as well as up the neck and into the face. There appeared to be normal resonance on both sides of the chest, but examinaiton was difficult because of the subcutaneous emphysema. The breath sounds on the right side were definitely diminished as compared to the left. X-ray examination of the chest revealed an extensive subcutaneous emphysema, no evidence of fractured ribs, a moderate pneumothorax on the right side, with partial collapse of the right lung and a shifting of the heart and mediastinum to the left.

Following the aspiration of 1,500 c.c. of air, the dyspnea improved markedly and the patient appeared to be quite comfortable. However, about three hours later the dyspnea and cyanosis reappeared and were as severe as on admission. A small rubber catheter was inserted into the right pleural cavity through the fourth interspace in the midaxillary line and continuous negative pressure at 15 mm. of mercury was maintained through the use of a water faucet filter pump suction apparatus. The patient was given oxygen by nasal catheter, and penicillin (15,000 units) was injected intramuscularly every three hours. The following morning he appeared to be so comfortable that the oxygen was discontinued. X-ray examination of the chest showed a disappearance of most of the air in the right pleural cavity. He remained in good condition during the day, but the following night his condition became much worse, and by the worning of September 8 there was marked dyspnea and cyanosis. Oxygen administration was resumed as his condition appeared quite critical. X-ray films of the chest revealed a massive atelectasis of the right lung with displacement of the heart and mediastinum to the right.

On the morning of September 8 he was bronchoscoped by Dr. P. G. Boman whose report reads as follows: Examination under general anesthesia revealed bloody mucus in the lower trachea and right bronchus. The mucosa of the right main bronchus was very red and edematous and torn along its superior, posterior aspect. The tear appeared to be between 5 and 10 mm. in length and about 15 mm. distal to the carina, with marked decrease in the lumen of the bronchus due to edema and congestion. The bronchoscope was not passed beyond the tear. No blood clots were found except the bloody mucus previously mentioned.

Following the bronchoscopy the child's condition remained about the same. The atelectasis persisted. However, by September 12 his condition had very definitely improved and the catheter was then removed from the right pleural cavity.

On admission his temperature ran between 101 and 102° F., pulse 130, respiration approximately 50 per minute. These remained at approximately the same level for the first four days and then gradually receded until September 12, when his temperature was normal, respiration 24 to 30 per minute, and pulse 100. His general condition remained approximately the same.

On September 22 he was again bronchoscoped by Dr. Boman, and this time, as the bronchoscope was introduced farther into the right main bronchus, a large clot was seen and removed. Behind this clot was about 15 c.c. of a serosangineous fluid, which was aspirated. Breath sounds over the right side of the chest, previously greatly diminished, now returned to normal. A chest x-ray showed a disappearance of the atelectasis and apparent normal expansion of the lung. He was then discharged to his home and apparently had no further

PLATE II. R. B.

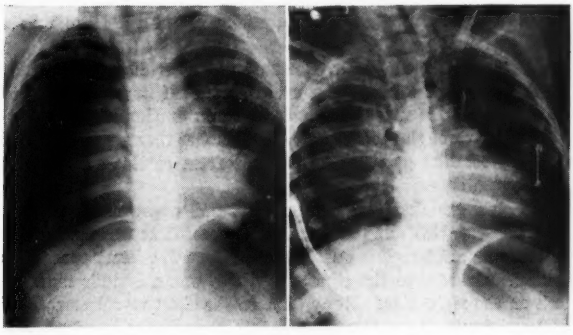

Fig. 1. Fig. 2.

Fig. 1.—Sept. 6, 1944. Day of injury. Right tension pneumothorax.

Fig. 2.—Sept. 7, 1944, tension pneumothorax relieved by suction on intercostal catheter. Subcutaneous emphysema.

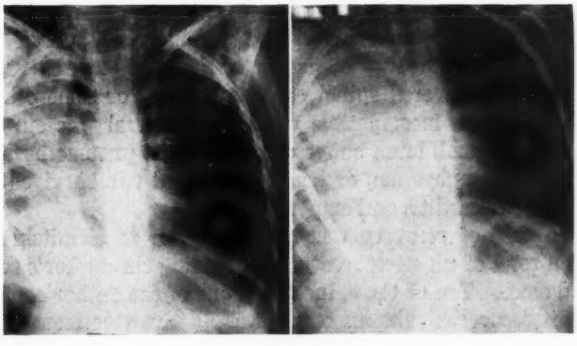

Fig. 3. Fig. 4.

Fig. 3.—Sept. 8, 1944, atelectasis, right lung.

Fig. 4.—Sept. 11, 1944, atelectasis, right lung.

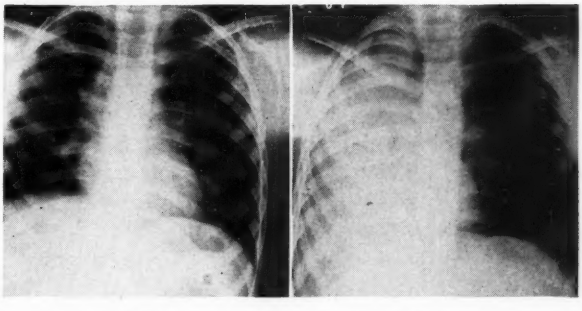

Fig. 5. Fig. 6.

Fig. 5.—Oct. 1, 1944, aeration, right lung, following bronchoscopic aspiration of blood clot and fluid distal to bronchial tear.

Fig. 6.—Oct. 9, 1944, return of atelectasis from bronchial stenosis.

trouble until September 30, 1944, when he was readmitted to the hospital because of attacks of coughing and cyanosis. Physical examination at this time revealed diminished breath sounds over the right side of the chest and x-ray films of the thorax again showed a marked atelectasis of the right lung.

He was again bronchoscoped by Dr. Boman on October 11, and a stenosis of the right main bronchus in the region of the tear was encountered. It was impossible to pass a bougie through this stenosed area. He was bronchoscoped again on October 22 and again it was impossible to pass anything through the stricture. No further therapy was advised. The parents were instructed to protect him as much as possible from catching cold. For about a year there was definite dyspnea on exertion.

The boy was again examined in March, 1946, and appeared to be growing normally. There was no evidence of scoliosis of the spine. The heart beat was maximum over the fourth interspace in the anterior axillary line on the right side. The heart tones were normal. The trachea was displaced markedly to the right, and there was a systolic murmur over the large vessels of the neck on the right side. X-ray films of the chest reveal marked overexpansion of the left lung. The right lung apparently was totally atelectatic and the heart entirely on the right side of the chest. The boy apparently has adapted himself very well to the right-sided atelectasis and apparently at this time is suffering no physical handicap so far as average activities are concerned.

An analysis of the time of death following bronchial rupture revealed that four patients died almost instantly and five more within one hour of injury, while ten succumbed after periods of five to ninety-six hours. Those dying within the hour did so because of associated injuries such as ruptured aorta or pulmonary artery, severed spinal cord or trachea, or some other injury or combination of injuries incompatible with life. Several who survived the immediate crisis to succumb later, suffered from tension pneumothorax in varying degree, mediastinal emphysema, or hemorrhage, and two survived long enough to die with acute pericarditis and empyema.

No known case of recovery was recorded prior to Krinitzki's[19] report in 1928, though a total of nineteen recoveries including the author's two cases have been reported since. Ten of these, including one of the author's, may be classed as spontaneous recoveries without any specific active treatment and without a true diagnosis at the time of the injury. Tension pneumothorax was recognized and decompressed by King[9] and by Bowen and May[11] in 1907, although both patients subsequently died fifty-five and twenty-six hours after injury. Recovery following active treatment by repeated decompression of bilateral pneumothorax and suprasternal incision to relieve intense progressive emphysema was first reported by Jones and Vinson[26] in 1939. A few, including one of the author's patients, have recovered under active treatment. Significantly, ten of the patients who succumbed did survive for a sufficient time to permit the institution of specific remedial measures if available in addition to decompression of tension pneumothorax and mediastinal emphysema which relieved the patient of mechanical embarrassment but did not remedy the underlying pathologic condition.

The first therapeutic considerations should be the administration of oxygen to correct anoxemia, the administration of blood and plasma to combat shock or hemorrhage, the aspiration of air from the pneumothorax side, or sides, to relieve intrathoracic tension and, if necessary, incision to relieve tension from mediastinal emphysema. If rib fractures are present associated with considerable pain, the use of sedatives or novocain block of the intercostal nerves of the

affected levels may be of distinct value. Care must be taken that the needles inserted for the block anesthesia do not penetrate the pleura and cause an accidental pneumothorax. A rapid accumulation of fluid within the chest usually means intrapleural hemorrhage, and its source must be investigated and controlled. The occurrence of mediastinal emphysema without pneumothorax should call attention to the possibility of bronchial or esophageal injury within the mediastinum. If blood is expectorated and there are no evident rib fractures to account for lung puncture, the possibility of pulmonary laceration or bronchial rupture must again be considered. If atelectasis develops, the possibility of retained blood clots must be investigated.

Early bronchoscopy should be done if bronchial rupture is suspected and the patient's condition will permit, for upon the bronchoscopic findings may depend the exact diagnosis and from this, the indications for further treatment. If blood clots are present in the lung, their removal is indicated in order to relieve atelectasis. Care must be exercised in bronchoscopic manipulation to avoid increasing the amount of trauma already present or restarting bleeding which has already controlled itself. Thoracoscopy through a cannula inserted for catheter decompression of tension pneumothorax may reveal visual evidence of bronchial rupture or the source of bleeding without serious strain upon the critically injured patient.

The prognosis in bronchial rupture depends, to a considerable degree, upon injury to adjacent structures in addition to the bronchial tear. If there is concomitant rupture of a pulmonary artery or vein, death is likely to occur quite promptly from hemorrhage. Less rapid bleeding from smaller radicals of the same vessels may prove fatal, but over a longer period of time. The tearing of the smaller bronchial artery may likewise prove disastrous in time because of the higher pressure behind it. Death may also accur from tension pneumothorax, the result of bronchial or parenchymal tear, unrecognized or unrelieved by those unfamiliar with its dangerous possibilities.

Some of these injuries, including bronchial rupture, may be amenable to surgical treatment, and the possibility of surgical intervention must be given due consideration and carried out if the patient's condition will permit. With modern anesthesia, the blood bank for multiple transfusions, and modern technique in thoracic surgery, the risk of an exploration might prove very slight as compared to doing nothing at all, and might well prove the means of saving the individual's life. It has been our experience in dealing with other serious traumatic situations, that with adequate anesthesia, sufficient blood to meet all needs, etc., surgery of a type to correct the shock producing lesion may be undertaken without waiting for the patient to come out of the shock state. The suture of an incompletely torn bronchus at the site most usually affected should not prove particularly difficult. Bleeding vessels can easily be controlled surgically. Care should be taken in controlling bleeding and suturing the lacerated bronchus, that the bronchial artery be not interrupted, for it is the nutrient artery to the lung and its interruption should call for excision of the lung or lobe involved. Two cases of bronchial repair following shell fragment injury at Anzio have been reported by Sanger[33] in 1945.

Complete rupture of the bronchus with pulmonary vessels and bronchial vessels intact may also present possibilities for bronchial suture and saving of the lung. Whether the lacerated bronchus accurately sutured will eventually heal with bronchial stricture and its complications is, of course, problematical. More serious damage should ordinarily call for lobectomy or pneumonectomy, depending upon the site of the tear. Anesthesia for such a procedure should ideally be administered through an intrabronchial tube with occlusive cuff inserted into the uninjured bronchus. Theoretically, then, this type of injury in its acute stage should present some possibilities for surgical attack and exploratory thoracotomy should be given serious consideration.

When a patient has survived the immediate injury, repeated bronchoscopy with aspiration of blood clots and dilation of developing stricture may be of therapeutic value. If stricture develops in spite of active treatment and the entire lung becomes atelectatic, the dyspnea, chest discomfort, and displacement may be relieved to a considerable degree by instituting a therapeutic pneumothorax on the affected side, maintaining sufficient collapse to overcome the high intrathoracic negative pressures which are associated with atelectasis and to hold the mediastinal structures at or near the midline. This form of symptomatic treatment is fundamentally sound and has been reported clinically by Clerf[29] and by Tyson and Lyle.[31] This will definitely relieve dyspnea, and will counteract any deleterious effects of mediastinal displacement and overexpansion of the contralateral lung. The risk of pleural complications during the maintenance of this pneumothorax should be minimal in the absence of underlying parenchymal pathology, and there is no reason why it might not be maintained indefinitely.

The possibilities of converting such a pneumothorax to an oleothorax should be considered, and might be a partial answer to the problem of repeated pneumothorax refills over long periods of time. The disadvantages of the weight of the large oil mass which might be necessary must be considered. Even with complete oleothorax, repeated observation would always be advisable. The possibility of reducing the marked negative pressure associated with atelectasis in the involved side by interruption of the corresponding phrenic nerve to allow diaphragmatic elevation might also be well worth considering. Extrapleural thoracoplasty as a late procedure to overcome the mediastinal shift and overexpansion of the contralateral lung might also be given favorable consideration. It might here have the same application as in the post-pneumonectomy patient.

All of the above considerations are applicable to the patient with complete bronchial stenosis without evidence of pulmonary infection. The patient who presents a bronchial membrane type of obstruction which can be recognized might be relieved by the bronchoscopic incision and destruction of the membrane to allow aeration of the lung (Piaget[27]). The patient who presents incomplete bronchial obstruction with infection will eventually develop bronchiectasis and infection in the lung distal to the stenosis. This type of patient would not be favorable for treatment by pneumothorax, diaphragmatic paralysis, or thoracoplasty, but rather should be considered for pulmonary resection as a means of eliminating the atelectatic, infected lung. (Author's case 1.) Mediastinal shift, displacement, and overexpansion of the contralateral lung will be less

following total pneumonectomy than from the atelectasis due to the bronchial stenosis, as the fluid and coagulant which fill the pleural space following pneumonectomy will occupy more space than the atelectatic lung removed.

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The American Association for Thoracic Surgery

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REPORT OF THE 1947 MEETING OF THE AMERICAN ASSOCIATION FOR THORACIC SURGERY

THE twenty-seventh annual meeting of the American Association for Thoracic Surgery was held in St. Louis on May 28, 29, and 30, at the Jefferson Hotel. This was the thirtieth anniversary of the founding of the Association. No meetings were held during the war years of 1942, 1943, and 1945.

Dr. Robert M. Eaton of Grand Rapids, Mich. was awarded the Rose Lampert Graff Prize for his paper, "Pulmonary Edema: Experimental Observations on Dogs Following Acute Peripheral Blood Loss." The scientific program was further highlighted by the presence at the meeting of the first person to survive a one-stage complete pneumonectomy which in his case was performed for carcinoma. He had been operated upon by Dr. Evarts Graham in April, 1933, and had engaged in the active practice of medicine since that time.

The Association voted to abolish numerical limits to membership, and limitation of time limits for associate membership, and voted to extend the privilege of associate membership to doctors in other countries, in addition to those in this country and in Canada. Amendments to the Constitution and By-Laws making these changes possible will be acted on at the next meeting. The numerical limitations were extended for this meeting by amendments to the By-Laws adoped on May 29. These amendments were worded as follows: Article IV, Section 2, of the By-Laws is amended as to the first sentence only, to read: "Active membership shall be limited to 150." Article IV, Section 3, was amended to read as follows: "Associate membership shall be limited to 150. The candidate, to be eligible, must be a graduate of a recognized school of medicine, but may be resident or native of any country whatever. The limited period of time for associate membership, as required by the Constitution, shall be 10 years.

The amendments to the Constitution which were read at the meeting and which will have to be acted upon at the next meeting are as follows: Article IV, Section 1., "There shall be four classes of members: Active, Associate, Senior, and Honorary. Admission to membership of the Association shall be by election. *There shall be no numerical limits on any class of membership.* Only Active and Senior members shall have the privilege of voting or holding elective office." Article IV, Section 2., "Election to all classes of membership shall be for life, subject only to the provisions of Section 3, following." (Section 3 deals with resignation and/or expulsion for cause.)

The following changes in membership status were voted by the Association:

1. That the Association accept, with regret, the resignation of Dr. R. H. MacDonald.
2. That the following Active Members be retired at their request to Senior Membership. Dr. Harold Neuhof, Dr. Leo Rigler, Dr. Herbert Carlson, Dr. Max Pinner.
3. That the following Associate Members be elected to Active Membership.

   Dr. Herbert D. Adams, Dr. Howard Barkley, Dr. Otto C. Brantigan, Dr. Thomas Burford, Dr. Andre Cournand, Dr. Richmond Douglas, Dr. Archibald J. Grace, Dr. John B. Grow, Dr. Dwight E. Harken, Dr. Harlon Harrison, Dr. George Humphreys, Dr. Louis F. Knoepp, Dr. Hiram Langston, Dr. Robert C. Major, Dr. F. R. Mautz, Dr. James L. Mudd, Dr. Paul V. O'Rourke, Dr. Forrester Raine, Dr. Samuel A. Thompson, Dr. David H. Waterman, and Dr. Mark H. Williams.

4. That the following candidates be elected to Associate Membership.

Dr. Frank F. Allbritten, Jr., 1025 Walnut St., Philadelphia 7, Pa.
Dr. Walter F. Bugden, Medical Arts Bldg., Syracuse, N. Y.
Dr. John Hughes Chandler, 420 E. Main St., Jackson, Tenn.
Dr. William Schmidlapp Conklin, 2718 S. W. Fairview Blvd., Portland, Ore.
Dr. Bert Hollis Cotton, Pasadena, California
Dr. Ralph A. Dorner, Dept. of General Surgery, University Hospital, Iowa City, Iowa
Dr. David J. Dugan, 2938 McClure Street, Oakland, Calif.
Dr. Walter William Fischer, 535 Park Avenue, New York, N. Y.
Dr. William O'Kelly Fowler, 322 E. Central, Box 462, Orlando, Fla.
Dr. Howard A. Frank, 483 Beacon Street, Boston 15, Mass.
Dr. Rettig Arnold Griswold, 323 E. Chestnut St., Louisville, Ky.
Dr. Rollins Hanlon, 1210 Southview Road, Baltimore 18, Md.
Dr. Albert Wilson Harrison, Medical Branch, Univ. of Texas, Galveston, Tex.
Dr. William Elliott Harrison, 710 Seymour Street, Vancouver, B. C.
Dr. Russell K. Hollingsworth, 1835 Eye Street, N. W., Washington, D. C.
Dr. Theodore R. Hudson, 55 E. Washington St., Chicago, Ill.
Dr. Felix Austin Hughes, Jr., Kennedy Veterans Hospital, Memphis 15, Tenn.
Dr. Gerard Anthony Patrick Hurley, 3001 Kent Avenue, Montreal, Que.
Dr. Ivan N. Ingram, 909 Hyde Street, San Francisco, Calif.
Dr. Winfield O. Kelley, Uncas-on-Thames, Norwich, Conn.
Dr. Harold A. Kipp, Mercy Hospital, Pittsburgh, Pa.
Dr. Karl Peter Klassen, Dept. of Research Surgery, The Ohio State University, Columbus, Ohio
Dr. Walter Ernest Kunstler, 5238 Queen Mary Road, Montreal, Que.
Dr. Adrian Lambert, Jr., 245 E. 72nd St., New York City, N. Y.
Dr. Edwin A. Lawrence, Salt Lake City, Utah
Dr. Joseph P. Lynch, 1180 Beacon Street, Brookline, 46, Mass.
Dr. Edward John McGrath, Cincinnati General Hospital, Cincinnati 29, Ohio
Dr. Lloyd H. Mousel, George Washington University, School of Medicine, 1335 H Street, N. W., Washington, D. C.
Dr. Donald L. Paulson, 723 Medical Arts Bldg., Dallas, Texas
Dr. William Ray Rumel, 807 Medical Arts Bldg., Salt Lake City, Utah
Dr. Edward Folland Skinner, 899 Madison Ave., Memphis 3, Tenn.
Dr. Frederick Cleveland Test II, David Whitney Building, Detroit 26, Mich.
Dr. Josiah Charles Trent, Duke Hospital, Durham, N. C.
Dr. Richard L. Varco, Dept. of Surgery, University of Minnesota Hospitals, Minneapolis, Minn.
Dr. Francis M. Woods, 1101 Beacon Street, Brookline, Mass.

The Association also voted to accept the proposals of the American Board of Surgery for the establishment of a subsidiary Board of Thoracic Surgery. At the meeting last year the Association had voted to enter negotiations with the American Board of Surgery for the establishment of such a subsidiary board. The Committee acting for the Association was composed of Dr. Carl Eggers as Chairman, and Dr. Jerome Head and Dr. Alton Ochsner. The American Board of Surgery insisted that candidates for certification would have to have three years of general surgical training and two years of thoracic surgical training. The majority of our committee favored two years of general surgery and three of thoracic surgery but when the matter was presented to the Association it voted to accept the requirements of the American Board of Surgery. The following motion was then passed:

That the Association authorize the President and Council, either directly, or through a committee, to continue negotiations with the Committee of the American Board of Surgery, for the purpose of

1. Organizing the American Board of Thoracic Surgery.
2. Establishing a Founders Group.
3. Appointing an Examining Committee.
4. Setting up requirements for training and certification of thoracic surgeons.

(Since the meeting the President has appointed the following committee to continue negotiations with the Committee from the American Board of Surgery: Dr. Carl Eggers, Chairman, Dr. I. A. Bigger, Dr. Brian Blades, Dr. Cameron Haight, and Dr. Richard H. Meade, Jr.)

In order to urge the government to give more active support to the fight against tuberculosis, the following resolution was passed by the Association at its meeting on May 29, 1947:

> The American Association for Thoracic Surgery, now in session in St. Louis, wishes to go on record as being disappointed at the continued lethargic and apathetic attitude of our government regarding the care of its tuberculous citizens. Tuberculosis is known to be a preventable disease which destroys and maims thousands of our people. The government is spending millions of dollars in investigating the causes of many diseases but, in comparison with the numbers of people affected, it is doing relatively little to control tuberculosis, which is a disease whose cause and prevention have long been known. It is not inaccessibility of funds that allows the apparent negligence to continue but inertia and lack of understanding on the part of our governing bodies. We therefore respectfully request that action be taken immediately to allocate adequate funds to the National Institute of Health and other governmental agencies for the study, treatment, and prevention of this disease.

The resolution was addressed to the Chairman of the Appropriations Committee of the House of Representatives. A copy was sent to him and to the Associated Press.

The following officers and new members of the Council were elected:

President, Dr. Alton Ochsner, New Orleans, La.
Vice-President, Dr. Edward D. Churchill, Boston, Mass.
Treasurer, Dr. William E. Adams, Chicago, Ill.
Secretary, Dr. Brian B. Blades, Washington, D. C.
Editor, Dr. Evarts A. Graham, St. Louis, Mo.
Council, Dr. I. A. Bigger, Richmond, Va.
Dr. Emile Holman, San Francisco, Calif.

The next meeting of the Association will be held at the Chateau Frontenac, Quebec, on May 31, June 1 and 2, 1948.